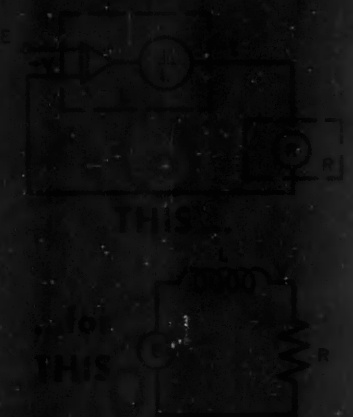
Control ENGINEERING

A NEW McGRAW-HILL PUBLICATION

Price 50 Cents

NOVEMBER 1954

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

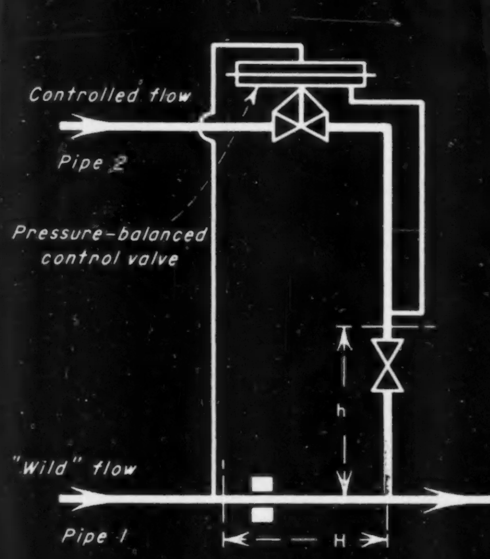


COMPUTERS

DIRECT SIMULATION BYPASSES MATHEMATICS

SYSTEMS

SIMPLIFIED RATIO CONTROL



COMPONENTS

ROUNDUP: 31 WAYS TO MULTIPLY

ALSO IN THIS ISSUE:

- What's Patentable in Automatic Control
- Basic Books for Your Control Engineering Library
- How to Design Speed-Switching Circuits

More Output...Less Work...

MORE PROFIT through Librascope's

COMBINED TECHNIQUES

Librascope's mechanical, electrical, electronic, optical and magnetic computer-controlling techniques, combined and coordinated in proportion to their effectiveness, have increased production with less effort and lower costs, and consequently resulted in greater profits in many industries.

Librascope's two decades of successful experience, manufacturing computers and components for military and commercial applications can be applied to many phases of your industry. Any problem will be given our full attention and resolved by using the technique that is found most suitable.

Please write today.

FOR EXAMPLE:

The Mohawk Carpet Company of Amsterdam, N. Y., uses General Electric Spectrophotometers for production control of raw stock dyeing to provide correct color values at a minimum of time, material and labor. An important component of this G-E instrument is Librascope's Tristimulus Integrator which gives integrated numerical values to colors and makes the spectrophotometer a practical production control tool. Since 1949 these units have served industry widely, providing another example of Librascope's ability to manufacture components under rigid specifications. Consult Librascope for solutions to your industrial control problems.

Engineers in search of interesting assignments, security, advancement—contact Dick Hastings, Personnel Director.

LIBRASCOPE

A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

LIBRASCOPE, INC. • 808 WESTERN AVE. • GLENDALE • CALIFORNIA

Control ENGINEERING

NOVEMBER 1954

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

FEATURE ARTICLES

IDEAS AT WORK

DEPARTMENTS

ADVERTISING INDEX page 106

PRINT ORDER THIS ISSUE 20,510

SHOPTALK FROM EDITOR TO READER

BOOKS, Books, books . . .

We don't sponsor a "book-of-the-month" plan for automatic control—not yet, anyway. We do, however, want to help the control engineer build an up-to-date library. So we've asked Prof. Thomas J. Higgins of the University of Wisconsin to write a series of three articles. The first, in this issue, deals with important books on industrial process control. Next month Prof. Higgins will discuss what has been published about servomechanisms and their applications. His final article will be on books about computers—the dynamics of business, simulation, etc.

But Prof. Higgins won't stop there. As a regular columnist he will continue to evaluate the new books in our field.

WHAT DO YOU KNOW ABOUT PATENTS?

We admit that we don't know enough about them to write a penetrating patent department. So we've called on another expert—Frank Rockett, a patent engineer. Frank will coordinate a series of feature articles designed to keep the control engineer posted on patents and patentability in his field. He promises not to plow through the Patent Gazette and unearth Rube Goldberg gimmicks. Instead he and his fellow experts plan a down-to-earth approach to such topics as: what is patentable? how to protect your patent rights? and what are the implications of recent court decisions?

As a starter, in this issue, Frank discusses the patent problems peculiar to automatic control.

LABOR LOOKS AT CONTROL

At their September convention in Atlantic City, the United Steel Workers of America forewent the pleasure of listening to a big-time politician. Instead they invited Prof. Gordon Brown to tell them about automatic control. We won't belabor the significance. But you should read what Gordon had to say, in the Industry's Pulse section.

WHAT DOES HE DO WITH HIS SPARE TIME?

Our nomination for the busiest control engineer alive is Sidney Davis, author of this month's roundup of multipliers. Sid is chief development engineer for Servomechanisms, Inc. In addition, he teaches two nights a week at Brooklyn Polytech, spends about 8 hours a week consulting for industrial users of automatic controls, and averages 50 pages per year of feature technical articles in McGraw-Hill magazines. This summer he found a fresh outlet for his energy. He took up golf.

FEEDBACK FROM READER TO EDITOR

Bouquets and . . .

To the Editor—

This publication is certainly a valuable contribution to the field of automatic control, and from the quality of the articles and the advertising, it is obvious that our engineers will be devoting many hours to it.

Ralph E. Cross
Exec. Vice-President
The Cross Company

To the Editor—

I was very much impressed by the first issue of Control Engineering. I was pleased to see that you intend to cover a broad range of interests from the theoretical to the practical.

Congratulations on the excellent job you are doing.

Rufus Oldenburger
Director of Research
Woodward Governor Co.

. . . Brickbats

To the Editor—

First number of Control Engineering received and read. It needs a lot of "controls" applied to proofreading, especially math formulas.

Lawrence Wainwright
Encinitas, Calif.

To the Editor—

After two pages of agreeing with the Editor that indeed it is desirable for symbols and terminology to be standardized, one is likely to decide a few pages further on [in Vol. I, No. 1] that the staff of Control Engineering spent too much time since January on the editorial and not enough on becoming familiar with what could be done and was not now.

Much progress in standardization of electrical and electronic symbols has taken place. May we suggest that your copy writers and draftsmen acquaint themselves with the AIEE and ASA standards and hereafter avoid the condition of "resistors" for grids in vacuum tubes and two different capacitor symbols in one article. "Pity the ambitious technician" who finds a symbol for an open contact used as a capacitor in a 1954 magazine and further on in the same issue finds it used as an open contact but identified with a letter "C" which to him is all the same.

However, we must agree that these are confusions which the editors of Control Engineering did not themselves originate, but let's not perpetuate.

W. L. Brown
San Diego, Calif.

From here on, we promise to adhere faithfully to ASA "Graphical Symbols for Electrical Drawings," Y32.2–1954, and "Abbreviations for Use on Drawings," Z32.13–1950. Despite our lapses, we feel just as strongly about the matter as Mr. Brown. The ASA committee on Terminology of Automatic Control is now forming. Marc A. Princi of General Electric is chairman, and ASME is the sponsoring society. This is the time for all control engineers to pitch in and help straighten out this language tangle.—Ed.

PROBLEM EXCHANGE

Contributions for the problem exchange are beginning to flow in. Next issue we'll start publishing this department.

Remember the procedure. Send in a control problem, illustrated with a line drawing, if appropriate. We'll print the most challenging in November and follow them with solutions a couple of months later.

The most interesting problems and the soundest, most imaginative solutions earn cash prizes.

For Informative Ads

To the Editor—

As a charter subscriber, may I take this opportunity to make a comment relevant to your advertising . . .

There are many items of equipment advertised in this Vol. I., No. 1 which

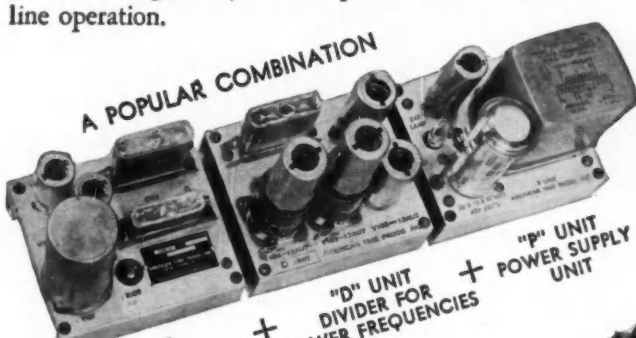
NOVEMBER 1954 **Control Engineering** VOL. 1, NO. 3

Published monthly by the McGraw-Hill Publishing Co., Inc. Publication office, 99-129 North Broadway, Albany 1, N. Y. Entered as second class matter at the post office at Albany, N. Y.
Executive, Editorial, and Advertising Offices: McGraw-Hill Building, 330 West 42nd Street, New York 36, N. Y. Donald C. McGraw, president; Willard Chevalier, executive vice-president; Joseph A. Gerardi, vice-president and treasurer; John J. Cooke, secretary; Paul Montgomery, executive vice-president, Publications Division. Ralph B. Smith, vice-president and editorial director; Nelson Bond, vice-president and advertising director; J. E. Blackburn, Jr., vice-president and circulation director.
For subscriptions, write to: Control Engineering—Subscription Service, 330 West 42nd Street, New York 36, N. Y. Orders must indicate company and position. Allow one month for change of address. Single copies 50¢. United States and possessions: $3 for one year, $4 for two years, $5 for three years. Canada: $4 for one year, $6 for two years, $8 for three years. Latin America: $10 for one year, $16 for two years, $20 for three years. Other countries: $15 for one year, $25 for two years, $30 for three years. Printed in U.S.A.

FREQUENCY STANDARDS *Modular system*

DESIGNED AS A *Modular system*

The Type 2001-2 series provides frequencies from 30 to 30,000 cycles with an accuracy of .001% (at room temperatures) in units suitable for integration with instruments of your own design — or for panel rack mounting with your own power sources — or for line operation.



WHICH WILL MEET YOUR

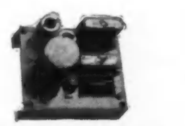
CUSTOM NEEDS

FROM A COMBINATION OF

STOCK UNITS

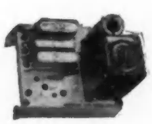
TYPICAL COMBINATIONS

2001-2	2001-2 + M
2001-2 + L	2001-2 + M + P
2001-2 + L + P	2001-2 + L + P + R
2001-2 + H	2001-2 + H + P + R
2001-2 + H + P	2001-2 + M + P + R

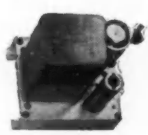


TYPE "2001-2" FREQUENCY STANDARD
Frequencies, 200 to 3,000 cycles. Output, approximate sine wave at 5 volts.

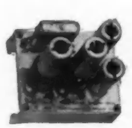
ACCESSORY UNITS



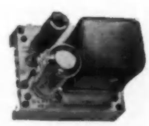
"L" UNIT.
DIVIDER, (MULTI-VIBRATOR TYPE)
Provides frequencies from 30 to 200, controlled by the 2001-2 unit.
Output, approx. 5V. Approx. sine wave.



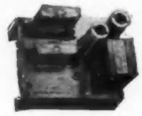
"M" UNIT
AMPLIFIER
Provides 2 watts at 6 and 110 volts.



"D" UNIT.
DIVIDER, (COUNTER TYPE)
Provides 40 to 200 cycles controlled by the 2001-2 unit. (fail safe)



"P" UNIT
POWER SUPPLY
Provides power for combinations of units illustrated, if other sources are inconvenient or not available.



"H" UNIT
MULTIPLIER
Provides frequencies from 3,000 to 30,000 cycles, controlled by the 2001-2 unit. Output, approximately 5 volts.

"R" UNIT
PANEL MOUNTING
Accommodates up to three units. Standard size is 8¾ inches high, 19 inches long.

For details, please request our "Type 2001-2" Booklet.

American Time Products, Inc.

580 Fifth Avenue ***New York 36, N. Y.***

OPERATING UNDER PATENTS OF WESTERN ELECTRIC COMPANY

are completely unfamiliar to me. In many instances, my interest is sparked in the possibilities for use beyond those indicated in the ads. The important aspect of this, I believe, is that my interest does not extend to writing to the manufacturer to obtain some idea of the general cost levels.

Where a representative general cost figure is listed in the advertisement, my interest will often be activated to the point of considering purchase; whereas items with no indication of the cost level present a psychological barrier, which probably loses sales for the advertiser.

To be specific, let me list your Giannini advertisement on page 4 as an excellent type of ad.

F. L. Avera
Director of Research
Rosefield Packing Co.

Elusive Article

To the Editor—

I have read with interest your first issue of Control Engineering. A magazine of this quality has long been needed in the control engineering field. However, I wish to point out what appears to be an error in the listing of a reference in Abstracts.

The article that I refer to was under the heading "Analog Analysis," page 128. The specific article was entitled "Test Models" and was erroneously listed as appearing in "Chemical Engineering," July 1954.

Robert B. Ball
Analysis Group
Bendix Aviation Corp.

The abstract was fresher than we indicated. "Test Models" was published in the August issue of "Chemical Engineering."—Ed.

Control Course at Home

To the Editor—

Do you know of any school or company that offers correspondence course in instrumentation?

A. R. Yanz
Design Engineer
General Foods Corp.

Yes. International Correspondence School offers an excellent course entitled "Industrial Instrumentation." Rated at 600 hours, it covers basic mechanical, chemical, and electronic engineering in its first division and applied instrumentation in its second. Course costs $195 and takes two and one-half years.—Ed.

Broad aisles swarmed with engineers—most of them young, all eager for information

Instrument Show Draws 20,000 Engineers

Instrument and Control Industry, Gathered Under One Roof in Philadelphia, Dramatizes its New Products, Fresh Ideas, and Enormous Growth Potential.

Never before had so representative a cross-section of the control field gathered in one place. For almost two weeks in late September the best minds and most elegant hardware were on display in Philadelphia's Convention Hall at the First International Instrument Congress and Exposition, sponsored by the Instrument Society of America.

Instrument and control engineers discussed more than 250 technical papers in upstairs meeting rooms. Meanwhile, beneath the ponderous green girders supporting the vaulted ceiling of the basement, 472 manufacturers from all over the world showed off their newest and best products.

The show was enough to excite even the casual visitor. All day long every day, a seemingly endless stream of people poured into the dingy limestone hulk of Convention Hall. Most of them were young men—quietly dressed and intense—notebooks crammed into their pockets. Here and there was a woman, or a gay group of men to whom convention meant frolic. Singly they arrived in taxicabs or on foot. Every ten minutes a bus swung to a stop at the front door and discharged a full load. (This was a welcome ferrying service between Convention Hall and the big hotels, provided by the Crawford Fitting Co.)

The gloomy stolidity of the building belied the activity on the basement floor. Broad aisles, separating brilliantly lit exhibits, swarmed with strollers. Up and down they meandered, stopping frequently to study equipment or question harried booth managers.

No eye could resist the glistening surfaces, varied textures, and color of the displays, nor the blinking lights and moving machinery. From every compass point, hissings, clickings, poppings, and whistlings clamored for immediate attention. Literature in every booth lured the information seeker and the catalog collector.

Almost without exception, every booth's design reflected the manufac-

Exhibitors from abroad included courtly Dr. Lange and Miss Berit Ericson of the much-photographed Swedish booth

turer and his line of products.

In particular, the Akashi Co. of Tokyo, displaying an electron microscope and hardness testers, blended Oriental tradition with Western technology. The clean-lined instruments stood on a straw abaca rug. The other furnishings were contemporary handicrafts of Japan—low stools and benches of clear birch capped with straw mats. The catalogs were hand-covered and hand-decorated. The casual visitor might well have lingered in hopes that tea would be served.

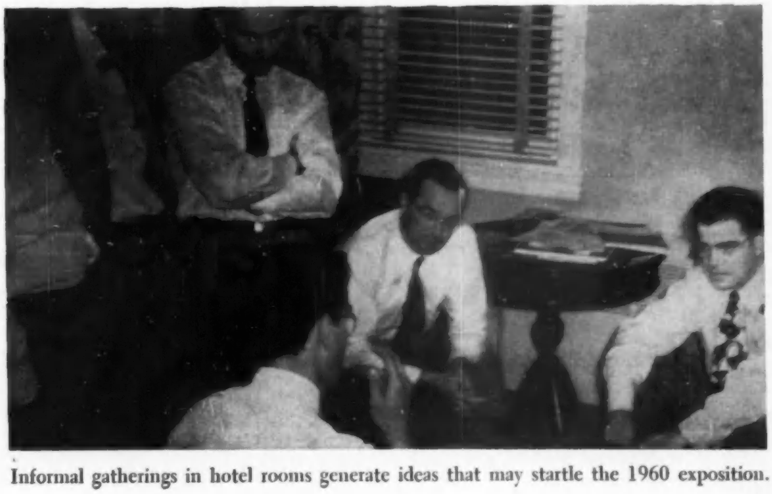
Ministering to a French display were two tousle-haired youths, dressed in rumpled tweeds. Everything about them suggested the longhair—certainly not the brisk American businessman. Presiding over one of the German exhibits, including an impressive flame photometer, was Dr. B. Lange of Berlin (see cut). His erect carriage, flowing white locks, and courtly bows were in the tradition of the Herr Professor.

The attractive Swedish exhibit, probably the most photographed on the entire floor, had Miss Berit Ericson in attendance (see cut).

From an analytical viewpoint, the exposition demonstrated that the control industry is fast becoming mature and well rounded. Every major facet was adequately represented. In number of booth-spaces—100 sq ft each—here is how much equipment each segment of the industry displayed:

Industrial Controls	117
Scientific and Quality Instruments	89
Transducers, Measuring Elements	86
Test and Inspection	72
Valves	62

This salesman is getting plenty of attention. But is he putting across his point?



Informal gatherings in hotel rooms generate ideas that may startle the 1960 exposition.

"Trouble with this kind of convention is there's no good old days to reminisce about."

Components and materials 47
Computers and Counters 45

The number of exhibitors and the total floor space has increased sixfold since the first ISA-sponsored show in 1946. The only disappointment was that relatively few of the servo manufacturers participated. There were nineteen representatives from this branch of the industry, but several prominent firms were missing.

Some of the highlights of the show had little direct connection with the displays. Among them were:

▶ Minneapolis-Honeywell's announcement that it had acquired Heiland Research. This move added an oscillograph line to the well-rounded M-H organization chart.

▶ Panellit's revelation that it had bought up the digital-converter end of Taller and Cooper. This helps fill the data-processing tool chest that Panellit is developing.

▶ The many job offers that filled the air. Plenty of the firms now breaking into the systems supply market are bidding for seasoned control engineers as salesmen. Pay is apparently growing with the field.

Technical sessions in upstairs meeting rooms drew unprecedented throngs. But as usual, some of the most important engineering ideas arose from informal gatherings in corridors and hotel rooms. At one of the most significant, a group headed by Prof. James B. Reswick of MIT discussed the possibilities of applying to practical engineering the time-series principles of Wiener, Tustin, and Shannon. A safe guess was that the ideas volleyed about this get-together would not sift down to the exposition floor much before 1960.

Europe's Most Impressive Tool Show Held in Milan

Concurrently with the instrument show in Philadelphia, Milan played host to the annual European Machine Tool Exhibitions. At least one U. S. builder who attended was so impressed with design developments that he cabled his chief engineer to fly over and take a look.

According to reports from "American Machinist" editors, the Milan exhibitions contained many items that deserve the attention of American control engineers.

Attendance, AM reports, broke no records, but most visitors seemed to be potential buyers, rather than mere sightseers. And although nothing revolutionary was on display, the 865 exhibitors tried to boost slumping tool sales by showing brand new machines and improvements that otherwise might have been held off the market for another couple of years or so.

Generally, the report observes, "European machine-tool design seems to be settling down, after extreme innovations the past few years. Although pushbutton controls were much in evidence, new machines are less complex and more restrained in design."

One European trend is the conversion of semi-automatic machines to fully automatic operation—by fitting automatic feeding and ejection. This trend was particularly noticeable in gear cutters. Pre-selectors of one sort or another were prominent on many kinds of machines. Even more common were copying devices.

Two new threading ideas attracted attention. One was a Swiss copying lathe that generates thread profiles. The other was a Belgian attachment that hydraulically controls an automatic decreasing infeed on screw-cutting lathes.

The Milan show was a shirtsleeve affair. Under the hot Italian sun, even the British shed their jackets.

"Dial a Diesel" is Remote Nursemaid for Locomotives

No one has to keep an eye on diesel locomotives parked on sidings of the Pittsburgh and Lake Erie Railroad. A new dial-telephone communications system protects them from vandals and keeps them warm in frigid weather.

The system's descriptive name is "Dial a Diesel." When an engineer leaves a locomotive, he plugs it in to a relay box alongside the track. This puts it under control of a central station at McKees Rocks, Pa.

When the diesel gets too cold or too hot, the system rings a bell in the locomotive. Picked up by an ordinary telephone mouthpiece, the sound is relayed to the station operator, who then gets busy on the phone. First he operates various codes to find out which engine needs attention. Then he dials a code number to start the engine, if it is in danger of freezing, or stop it, if it is overheated. Should anyone pull the trackside plug, the disconnection registers on the control board.

The beauty of the new system is that it uses existing telephone lines and can operate over any distance. In tests, P&LE locomotives have been started as far away as New York. Then too, the operator can hear what is going

on in the remote locomotive. If he is starting a diesel, he hears fuel pump work and engine start cranking.

The system, which can control 241 locomotives on one telephone circuit, was invented by two P&LE employees —superintendent of communications Dale W. Shackley and manager of equipment James J. Wright.

Committee Activity In the IRD, ASME

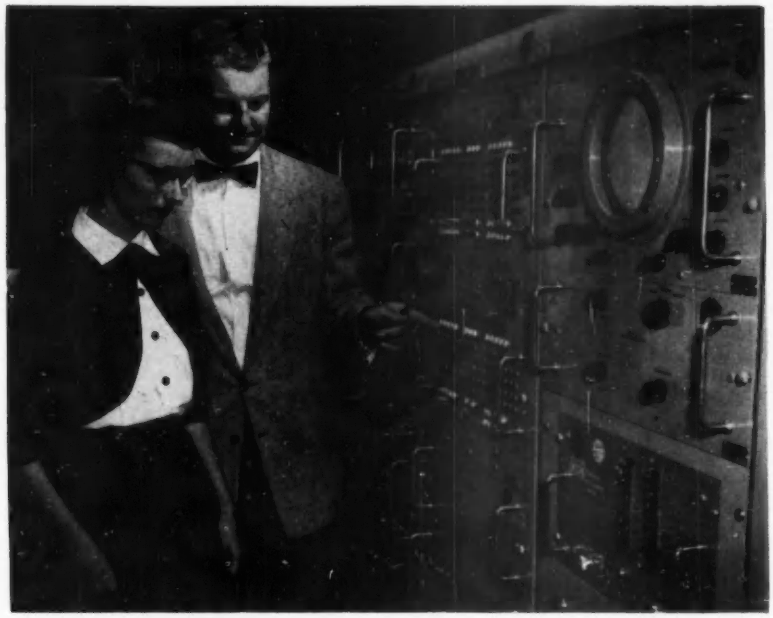
The Executive Committee met at Ocean City, N. J., Sept. 18, in the summer quarters of Chairman W. E. Belcher. After jogging on the boardwalk, the Division approved the plans for a conference to determine the dynamics of:

- Inanimate physical systems
- Human operator and systems including him
- Economics, business, social science

Dr. J. A. Hrones of MIT is chairman of the conference, which will be held at the University of Michigan, April 25-26, 1955. Professor G. V. Edmonson is handling local coordination.

Professor Edmonson becomes chairman of the IRD Application Committee at the end of this year. Ralph E. Clarridge, retiring Application Committee chairman, has accepted the general chairmanship of a symposium on non-linear control systems, proposed for April, 1956.

Hrones organizes first IRD Conference



Van Doren demonstrates the new Douglas telemetering and data-reduction system

Data-Reduction System Evaluates Flight Tests

Douglas Aircraft engineers are testing the Navy F4D Skyray with a new telemetering and data-reduction system. So fast is this system that it can produce 216,000 points of information during a one-hour test flight.

M. L. Van Doren, Douglas research engineer, had this to say: "To read this information on film, plot, and tabulate it would require 3,600 man-hours at a minimum. If six men working 8-hour days, with no lunch periods, were interpreting this data, it would take 75 days to reduce."

The system consists of an 88-channel airborne unit, which relays readings to the ground station and computer, housed in a trailer van. The station can tabulate and print six channels of information per second.

Around the Business Loop

▶ American Chain and Cable Co. has bought the Bristol Co., one of the firms that pioneered instrumentation and automatic control in the U. S. ACCO, which paid about $7,600,000 for almost all the outstanding stock, plans no changes in Bristol's personnel or policy but will complete an expansion program started at Bristol.

Bristol was founded in 1889 in Waterbury, Conn., to exploit the inventions of William H. Bristol. Today its industrial products include automatic controls, recorders, and telemetering equipment for temperature, high pressure, vacuum, draft, flow, pH, liquid level, humidity, voltage, current, power, motion, and speed. Its military aircraft instruments include engine-temperature controls, timers, and transducers.

▶ In rapid succession, Electro Dynamics Corp. of Beverly Hills, Calif., changed its name to Litton Industries, and bought the precision manufacturing firm Birklan Corp. of Mt. Vernon, N. Y. Litton Industries, one of the fastest rising companies in automatic control and data processing, formed last November. Financed through Lehman Bros., New York banking firm, it already operates four plants.

▶ Robertshaw-Fulton opened a new four-story $1 million research center at Irwin, Pa. The firm started half a century ago in a basement where Frederick W. Robertshaw tinkered with automatic controls for water heaters.

Expanding in another direction, R-F broke ground for a $2 million plant at Milford, Conn., on the outskirts of Bridgeport. The new works are almost twice the size of the firm's present Bridgeport Thermostat Division plant.

► Other new building ventures in the control field include: two by the Foxboro Co. in Pittsburgh, Pa., and San Leandro, Calif.; a $500,000 plant started by Servomechanisms, Inc., to manufacture electronic and electromechanical control systems in Los Angeles; two additions to the Metuchen, N. J., plant of Gulton Industries; and a $350,000 building just completed by Lear, Inc., in Santa Monica, Calif.

Bryant: To Atlantic Research from ERA

Mock: New exec. v-p of General Metals

Automatic Assembly Cuts 21-in. TV Price to $150

Automatic assembly is saving time and reducing cost for the Admiral Corp. Vertically-mounted printed-circuit chasses are saving space, too, inside the cabinets of their 21-in. television sets. The new sets are 5 in. shorter. They sell for $150.

A 30-ft-long complex of automatic machines gobbles up resistors, capacitors, and inductors and spews forth completely assembled printed-circuit boards every few seconds. Eight tubes are used on this chassis.

The electronically-controlled assembly equipment was designed and built by Admiral engineers, under the direction of C. S. Rossate, vice-president.

Printed circuit-boards are photo-etched and stamped by Admiral. Fifty assorted components are assembled on the board, two and three at a time.

John B. Huarisa, executive vice president of Admiral cited the advantages of the new production system: "more uniform production, trouble-free soldering, greater resistance to extremes of temperature and humidity, more flexibility of engineering, and lower production costs in these highly competitive days."

Admiral technician inspects etched and stamped boards before circuits are printed.

Important Moves By Key People

► Harold J. Mock is the new executive vice-president of General Metals Corp. and also general manager of its Adel Precision Products Division. Mr. Mock directed guided-missile manufacture for Hughes Aircraft, and before that was director of industrial engineering for Ford Motor Co. At Adel Precision Products, Mr. Mock will modernize the division's hydraulic and pneumatic equipment line and add items tailored for supersonic flight applications. To assist in this program he has promoted John W. Kelly to vice-president of Adel.

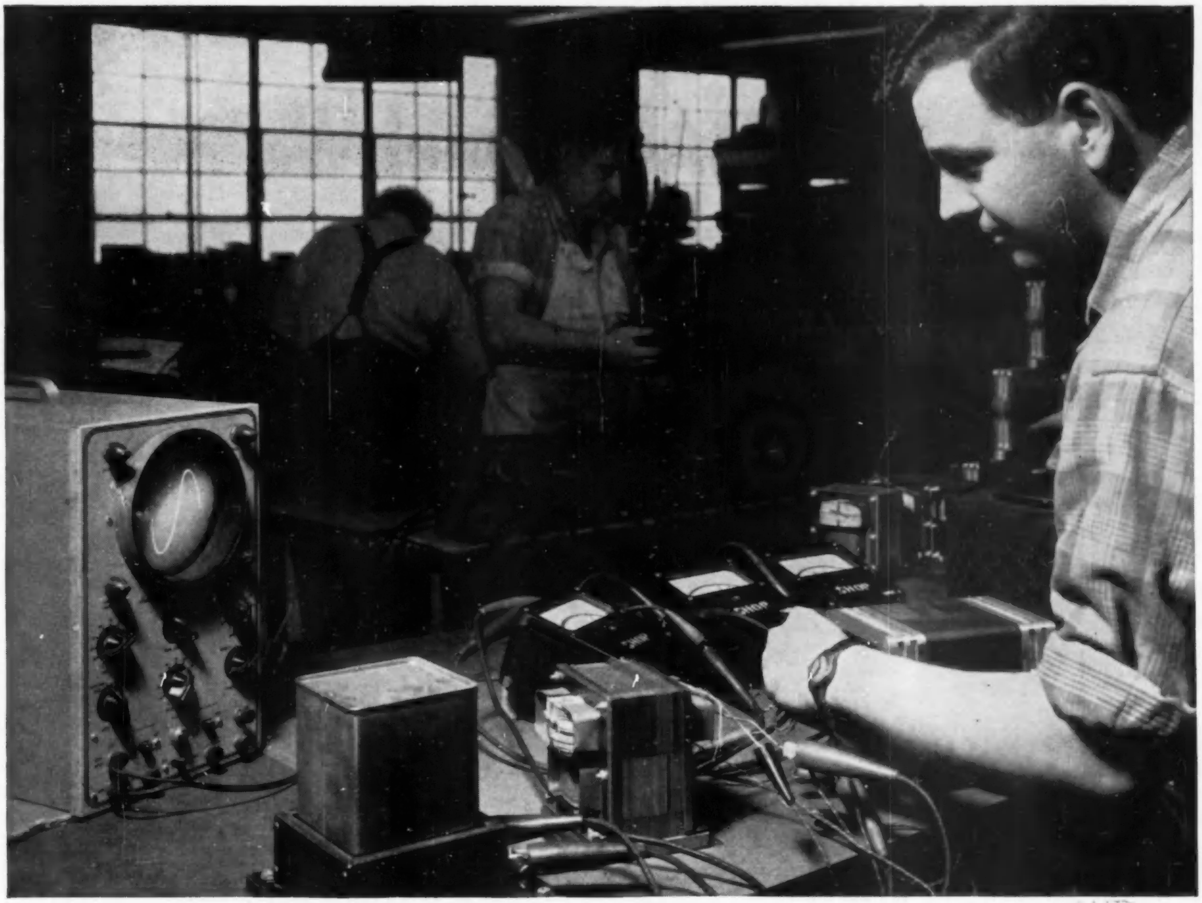
► Woodford D. Miller and Wilbur Jackson are now vice-presidents of Robertshaw-Fulton Controls. Mr. Miller will continue to manage the company's Robertshaw Thermostat Div.

► John F. Bishop has been appointed general manager of Beckman Instrument Co.'s Beckman Division.

► Paul Koch, veteran instrument engineer, is now assistant general manager of Ruge-deForest, Inc. Formerly a consultant for the company, he was works manager for Norden Instruments, and spent 21 years with Bendix Aviation and Manning, Maxwell & Moore.

► Robert A. Canning, formerly manager of production engineering, has been named manager of quality control by General Electric's Carboloy Department.

► Royal C. Bryant is the new director of Atlantic Research Corp.'s Electromechanical Division. He was research director for Engineering Research Associates Div. of Remington Rand.



Individual adjusting of neutralized, magnetic voltage regulators guarantees less than 3% harmonic distortion

You can provide a stabilized source of undistorted voltage with a Sola Harmonic Neutralized Constant Voltage Transformer (Type CVH). Like Sola Standard Type CV stabilizers, each harmonic neutralized unit is individually adjusted during manufacture to regulate within ±1% regardless of voltage fluctuations as great as 30%. In addition Type CVH regulators deliver sinusoidal output with less than 3% distortion. Operation is automatic and instantaneous. There are no moving parts, no manual adjustments, no maintenance.

They are available from stock in the following va output capacities: 60, 120, 250, 500, 1000 and 2000. Input voltage range of 95-125v with regulated output of 115v. Custom units made to specification for production quantity orders.

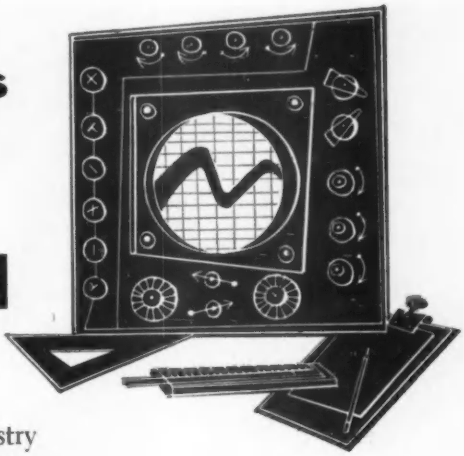
Sola type CVH regulators may be used for the most exacting applications with equipment having elements which are sensitive to power frequencies harmonically related to the fundamental. They are especially suitable for input to a rectifier when close regulation of the dc output is required. Available from your electronic distributor.

SOLA *Constant Voltage* **TRANSFORMERS**

Write for literature describing these and other Sola Constant Voltage Transformers. Ask for Bulletin 26K-CV-200.

Transformers for: Constant Voltage • Fluorescent Lighting • Cold Cathode Lighting • Mercury Vapor Lighting • Plastic Signs
SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414 • *BOSTON:* 272 Centre Street, Newton 58, Massachusetts
NEW YORK 35: 103 East 125th Street • *LOS ANGELES 26:* 2025 Sunset Boulevard • *PHILADELPHIA:* Commercial Trust Building
CLEVELAND 15: 1836 Euclid Avenue • *KANSAS CITY 2, MISSOURI:* 406 West 34th Street • *Representatives in Other Principal Cities*

INDUSTRY'S PULSE



Labor Looks at Control

Dinner clothes in a steel mill? "Steel has become an industry wherein I would not think it facetious if the workmen wore tuxedos on the job."

When Gordon S. Brown said this on Sept. 20, he was not trying to raise a guffaw. Rather, he was dramatizing automatic control to 3,000 delegates of the United Steel Workers of America, CIO, who filled cavernous Atlantic City Convention Hall for their union's Seventh International Convention.

Will Control Undermine Unions?

To union leaders automatic control is an enigma. Does it foreshadow mass technological unemployment or a golden age of universal leisure? Will it destroy labor organizations or magnify their influence? The men who run the Steel Workers, the nation's second largest union, wanted to know: "What does it mean to me." Thus had they invited to be their main guest speaker the head of MIT's Electrical Engineering Department, instead of the customary political bigwig.

After explaining the nature of automatic control and holding forth on his pet topic, "serendipity"—the knack of finding things you aren't looking for—Gordon got down to the main sociological points. "To me," he said, "the really important consequence of the mushrooming of [automatic control] is that our jobs will change. I think the change in the character of jobs will be substantial, but I do not believe that the consequences need be catastrophic."

Men Must Grow into Bigger Jobs

The laboring man will have to keep a flexible mind in order to adapt to a job upgraded by the growth of control. "This is not a situation to be taken lightly, because it is through labor's inability to procure this upgraded job that we precipitate technological unemployment . . . Failure to qualify for the upgraded job often hits at the engineer and even the scientist . . . New developments in science, such as the discovery of transistors and magnetic amplifiers . . . jolt the complacency of whole armies of engineers, some even who started their careers only a decade ago."

As a "person who observes this drama from the ivory tower of a technical institute," Gordon deplored the attitude expressed by such blithe assertions as: "Automation will displace labor, but since it will create upgraded jobs, everything will be lovely." In

his opinion, too few people worry about how the displaced worker will move into his new and more expert assignment.

Pointing out that rapidly changing technology favors the young man, recently trained in new theories and techniques, Gordon continued: "We can't overlook the fact that oldsters still have to play . . . Creating the opportunity for both oldsters and youngsters to move into a better job—an upgraded job—may become an issue of importance comparable with that of higher wages in a job classification that soon may not exist."

Chance to Upgrade May Become Major Bargaining Point

Who is to fit men for new jobs? Gordon advised management, technical men, and labor leadership to cooperate in appraising and planning for the inevitable technological change.

"Planning by labor should be to ensure that its leadership is kept fully informed about the technological developments in its industry. In its research effort it should be constantly in contact with what is happening in science and engineering. Its members should be represented in the technical professional societies. It should keep abreast of industrial and university research."

"Its planning should also involve, among other things, the continued examination of its policies with respect to such matters as pensions, job classifications, and wages. It should face up to the reality of job upgrading. The fluidity of the time requires mobility of policies affecting labor in the fields of [automatic control]. Labor should seek an industrial environment wherein it will have elbow room and the capability to move around. The unvested pension, in contrast with the vested pension, and the inflexity that might lurk in a rigid job classification program, look like strong deterrents to this mobility."

Summing up, Gordon declared that automatic control "will mushroom, that we want it to mushroom, and that we couldn't stop it even if we wanted to. It will bring great change to all of us. To keep its consequences in bounds, first we will have to appraise and then to plan. Then if we will reappraise as we plan, we will, in effect, step upward from a simple cause-and-effect relationship to the more powerful cause-effect-plus-feedback relationship. Then we will find an opportunity to exercise control.

"And in the course of planning, we shouldn't ignore serendipity, because we may run across some wonderful ideas we were not seeking."

A lot of hard sense and the framework for constructive action showered down upon the steel workers from Gordon Brown's ivory tower.

SPEED KING

SOLENOID PILOT OPERATED CONTROL VALVE

by VALVAIR

DESIGNED AND BUILT TO J. I. C. STANDARDS

- **A Hefty Assist to Automation**
- **Fully Enclosed**
- **Integral Junction Box**

The Valvair line broadens again — with Speed King's exclusive features. All parts are totally enclosed. The Speed King will operate submerged in water or buried in sand. Simplicity! — only two moving parts. Molded coil — no wear or shorting out. 20,000,000-cycle life and more. Speed King is industry's most rugged and compact valve.

Other features: for pressures from 35 to 200 p.s.i. pneumatics, hydraulics, vacuum; complete line—2-way, 3-way, 4-way and 4-way-5-port (2-pressure) models; foot or sub-base (manifold) mounting; pipe sizes —¼", ⅜", ½", ¾", and 1".

Ask for Bulletin "CE-11".

Representation in: BALTIMORE • BIRMINGHAM • BOSTON BROOKLYN • BUFFALO • CHARLESTON, W. VA. • CHICAGO CLEVELAND • CRANFORD, N. J. • DAYTON • DENVER DETROIT • EUREKA, CALIF. • GLENSIDE, PA. • HOUSTON KANSAS CITY, MO. • LOGANSPORT, IND. • LOUISVILLE MILWAUKEE • MINNEAPOLIS • PASADENA • PITTSBURGH PORTLAND • ST. LOUIS • SAVANNAH • SEATTLE MONTREAL • TORONTO • VANCOUVER

VALVAIR CORPORATION *Affiliate: Sinclair-Collins Valve Company* 1010 BEARDSLEY AVE., AKRON 11, OHIO

Rely Upon Valvair DIVERSATILITY

Control ENGINEERING
NOVEMBER 1954

Gaps in the Literature

Take a look at the voluminous technical literature of automatic control. It treats control systems as if they were information-handling systems—which they are. And this is a healthy approach, for it gives the theorist and the application engineer in our field a universal viewpoint.

Applications of signal coding, noisy-signal handling, statistics, and data sampling progress satisfactorily.

Further in the van is the work on nonlinearities. When the control theorist broadens his outlook to recognize nonlinearities, he frees himself from step-by-step thinking that throttles his progress.

But something is missing.

Control systems, after all, must do useful work—a fact we too often forget in our haste to analyze them with the mathematics of circuit theory. A control system is a power modulator. Impossible demands on its power source can completely frustrate the hardware-transformation of a system designed for high performance by the message-handling approach.

It is high time that we enlarge the communications philosophy to include power requirements. The literature contains too little source material on this aspect of control. What there is, however, shows that relationships between power and fidelity can be established. Sound test methods exist. Find the energy-transfer capabilities of a system and you can design it for adequate continuous and standby power.

What other concepts of power are there?

Go back to the fundamental objective of control: the balancing of demand power with supply power. Think of it as automatic impedance matching.

Think of regulating an industrial process by optimizing production "power" with respect to cost.

Here is a new salient. It deserves the attention of the best minds in our field. The opportunity is open for significant research that will lead to who-knows-what new concepts.

THE EDITORS

What's Patentable In Automatic Control?

Patents in this new industry will be extraordinarily complex. With few exceptions, they will emanate from teamwork research. But recent changes in the U. S. Code make it easier for management and patent-minded engineers to cope with their patent problems in automatic control.

FRANK H. ROCKETT, Airborne Instruments Laboratory

Essential to any industry are the patents that define the intellectual property on which it is founded. In the electronic industry, for example, a clear-cut starting point is the patenting of such inventions as radio transmission and thermionic vacuum tubes.

Automatic control, on the other hand, is an outgrowth of existing industries. The industry may appear, at times, to be new more in magnitude than in kind. As any field matures, it gradually becomes more complex. But what sets automatic control apart as a new industry is that the increased complexity has come about at an accelerating rate through the past decade by the combining of instruments with production and handling machinery.

Some spectacular developments may prove unpatentable combinations

The nature of automatic control suggests an important characteristic of the patents that can be expected. Because many of the innovations will be aggregations of existing technologies and equipment, even some of the most spectacular developments may prove unpatentable as being simple combinations. The inventions that are made, however, will be highly complex.

For example, U. S. Patent 2,604,262, B. E. Phelps and G. E. Mitchell, issued July 22, 1952 for a Multiplying and Dividing Means, consists of 146 sheets containing 89 figures and 280 columns of description and 36 claims.

U. S. Patent 2,636,672, F. E. Hamilton, R. R. Seeber, Jr., R. A. Rowley, and E. S. Hughes, Jr., issued April 28, 1953 for a Selective Sequence Electronic Calculator (the IBM 700-series computers), sets forth 110 claims. Until recently most patents contained about 3 claims.

The new patent codification act reverses the trend in court decisions, which had insisted that invention be the consequence of a stroke of genius. It also acknowledges invention through the concerted efforts of research teams. Thus it endorses the complex type of invention that will dominate the art of automatic control.

The exact language (Title 35, United States Code, section 103) is "Patentability shall not be negatived by the manner in which the invention was made." The background of this provision (The New Patent Laws, A. Boyajian, Electrical Engineering pp 861-5 Oct. 1953) is a variety of court decisions concerning validity of patents in which effort was made to evaluate invention in terms of a "flash of genius" or an abrupt significant advance in the art. This is an oversimplification of the psychology of creative thinking—as research executives have recognized for some time.

The chemical industry has had some experience in inventions of this magnitude in its continuous processing plants. Some machine tool patents offer

a foretaste of what is coming. But little inventive effort of such magnitude has been evident until recently in most other industries from which automatic control derives its full flood tide. Here are implications for management and engineers.

Control makers and users may jointly sponsor research programs

Management is responsible for organizing a research team whose professional members have diverse backgrounds and abilities. It is difficult to assemble such a team and to keep the attention of its members focused on a particular problem, and yet to allow the individual members sufficient freedom for speculative unfettered thinking. The long-range planning and long-range financing required to carry out such complex and protracted developments may call for companies that are larger than most in other industries. And there may be considerably more jointly sponsored research and development programs between control makers and users.

If such joint research and development becomes common practice, the patent terms of contracts and licensing agreements may evolve into a pattern unique to the industry. Most highly technological industries adapt licensing practices to their peculiar organizational structures. The chemical industry leans toward relatively independent areas of patented specialties. The oil industry licenses in broad fields with technological assistance therein. The electronic an invention, which is in fact a coherent concept, industry often cross licenses patents for circuits and equipment but seldom licenses those for small components and parts.

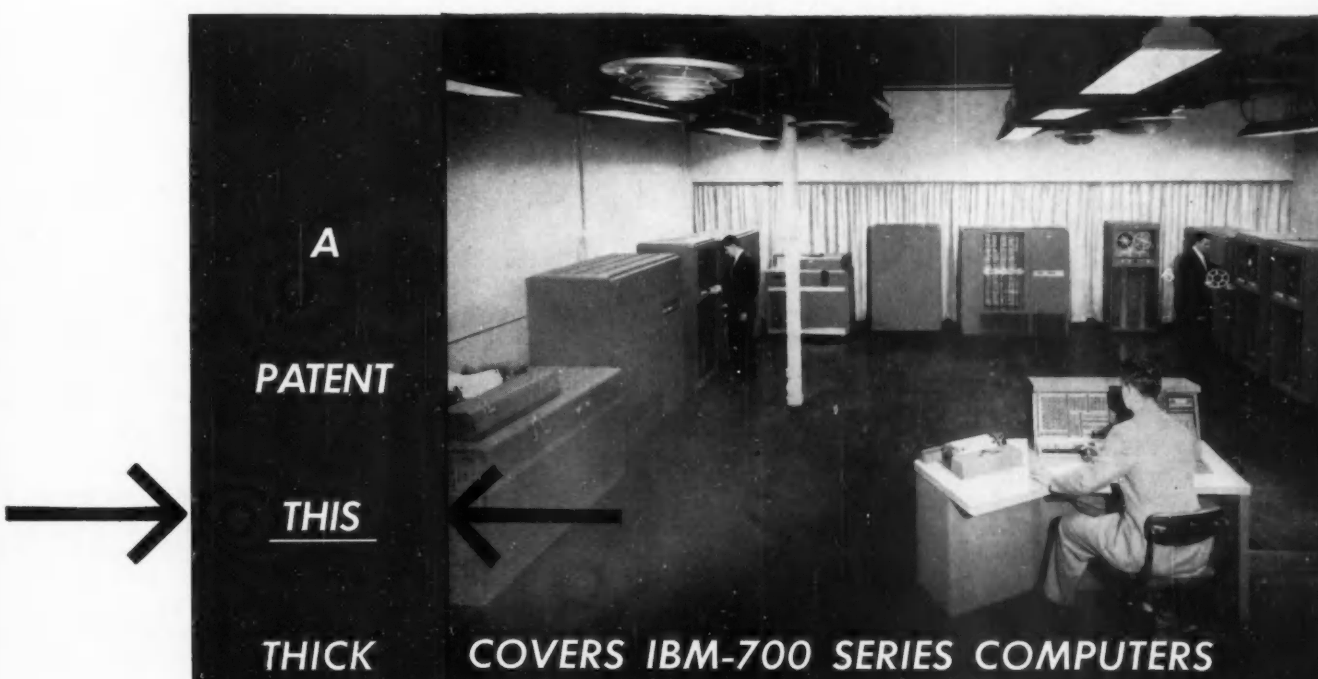
The inventor must be a patient problem solver

The engineer is not likely to make a significant individual contribution to automatic control. Yet innovations such as those disclosed in the patents mentioned earlier are the creative contributions of only a small group of inventors. Previously, engineers became inventors because they had inventive knacks. Now, frequently, their supervisors recognize they are adept at solving problems and assign them to problems with inventive possibilities.

The power of concentration required simply to digest patents for such inventions demands considerable mental stature. The mental grasp and scope of comprehension needed simply to understand the problems are much greater than usually required to appreciate the background of most patents. The continuity of effort necessary to examine each facet of the invention and make sure that it is indeed workable requires a patience that the dreamer seldom has.

Each automatic-control patent stems from diverse technologies

Each significant advance creates the need to reshuffle classifications. Thus in automatic control



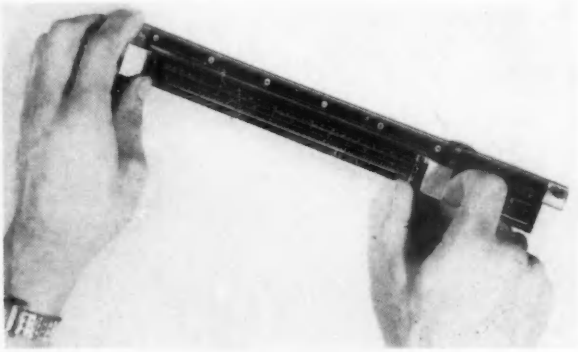
Author Rockett is patent engineer at Airborne Instruments Laboratory, Inc., Mineola, N. Y. His activities include preparing invention disclosures and advising management on the influence of patent policy, especially as a stimulus to original thinking.

brings together within one disclosure subject matter from several existing patent classifications.

The industrial revolution, as such, was based on the noninventive process of converting manually operated machines into power-driven machines. Similarly, the automatic control industry is founded on the noninventive step of bringing together many parts which perform their conventional functions and, for the most part, produce no new result. Rather, they work harmoniously together—although popularizers of the industry may well present the change in magnitude in such spectacular language as to suggest that it is indeed a change in kind.

But the fact that the industry stems from noninventive, unpatentable combination indicates that no company, large or small, can have a monopoly on automatic control in its rudimentary form. The simple compounding of devices is open to everyone. Each team of inventors will distinguish themselves by redesigning individual equipments to cooperate more effectively with one another and by arranging already complex equipment to produce new and useful, and thus patentable, results. And it is this patentable distinction that defines automatic control as an industry apart.

Data Reduction by Stretching



Make one setting against the recorded magnitude at the low-frequency end, and read the magnitude ratio directly at any other frequency. Phase angle and frequency can be measured just as easily to three significant figures, directly from an oscillographic record or other plot. It is not necessary to know the scale of the plot.

The instrument that performs these wonders is called a Variable Scale. It is manufactured by the Gerber Scientific Instument Co., of Hartford, Conn.

The Variable Scale makes it easy to:

- ▶ Multiply and divide graphically
- ▶ Read distances directly on odd-scale drawings
- ▶ Measure short lengths accurately
- ▶ Interpolate linearly or logarithmically between curves
- ▶ Plot an accurate log scale of arbitrary length

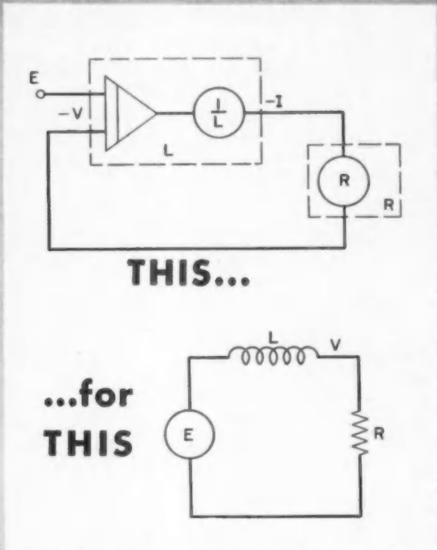
A calibrated triangular spring is the heart of the instrument. It has 100 coils, every fifth one colored green, and every tenth one red. The rest are white. Adjacent to the triangular spring, a round spring expands and contracts, carrying small disks marked 0, 2, 4, 6, 8, and 10. These serve to calibrate the 0th, 20th, 40th, etc., coils of the triangular spring.

The round spring winds tightly around a small bar, along which it must slide. This provides some friction damping for the inertia of the disks. The triangular spring hangs freely between its ends.

A Plexiglas parabolic lens protects the springs and makes them appear to be at the surface of the lens. This enables the user to align the instrument precisely with a graph. Measurements are definitely reproducible. The triangular spring, at full extension, is accurate to .005 in. between any two coils.

THE GIST: A computer model can predict many things about the performance of a control system; especially about the difficult-to-analyze dynamic behavior. Deriving the computer circuit, however, presents its own problems. And the results are not always easy to analyze.

This article describes a concept which simplifies simulation. The computer circuit is built from functional blocks, which are direct analogs of components in the system to be simulated. The system's dynamic equations need never be written. Manipulation of one of the computer's potentiometers affects a property of only one component in the system. Analysis becomes simpler.



Direct Simulation

BYPASSES MATHEMATICS, SIMPLIFIES ANALYSIS

VERNON L. LARROWE, University of Michigan

A SIMPLE R-L CIRCUIT and a computer circuit that directly simulates it are shown in Figure 1. The drawing suggests a direct correspondence between elements of the electrical network and elements of the analog computing circuit. The three types of linear circuit components—inductance, capacitance, and resistance—may be represented by analog elements as shown in Figure 2.

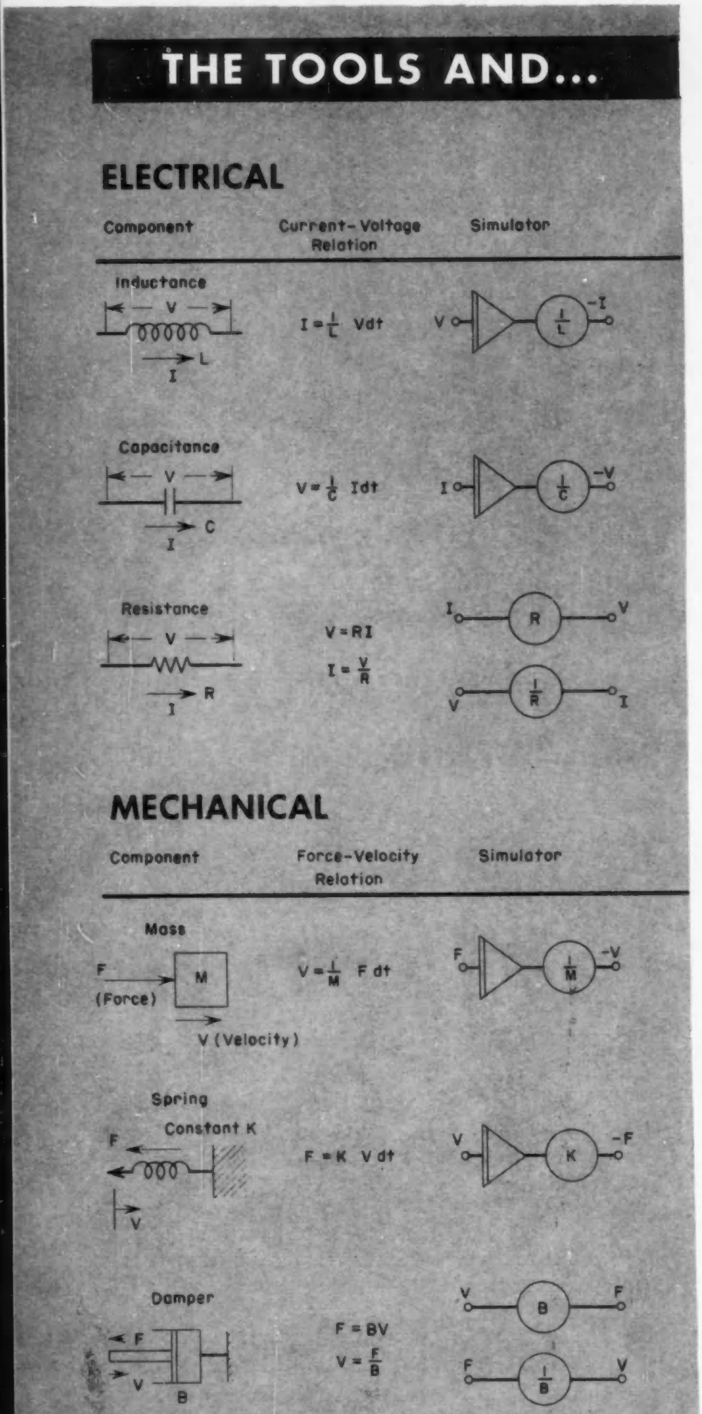
An inductance integrates the voltage across it to produce current. It may be represented by an electronic integrator connected to a potentiometer. The input to the electronic integrator represents the voltage across the simulated inductance. The output of the computing circuit is a voltage, which represents the resulting current in the inductance. The potentiometer set to $1/L$ may be placed in either the input or output circuit of the integrator, whichever is most convenient, as long as the value of L remains constant with time.

Similarly, a capacitance may be simulated by an electronic integrator connected in cascade with a potentiometer set to $1/C$. The input to this circuit represents current, and the output represents voltage. The voltage-current relationships in a resistance may be represented by a potentiometer as shown.

Using The Tools

Using Kirchoff's laws (1, The sum of the voltages around a closed loop is zero, and 2, The sum of the currents flowing to a junction is zero), these analog simulators of components may be assembled to simulate an entire electrical circuit as shown in Figure 3.

The method for its derivation is easy to trace. For example, the voltage across the coil L_1 in the circuit



Output of analog simulator is a voltage proportional to force, velocity, current, etc. Input is a voltage proportional to net force, net velocity, etc., acting on component. Fig. 2

is $E_1 - V_1$. Thus, feeding E_1 and $-V_1$ to the upper left integrator on the computer "road map" and multiplying the integrand by $1/L_1$ produces $-I_1$. The minus sign is the result of signal inversion by the electronic integrator. The voltage corresponding to $-I_1$, obtained in this manner, is added to a voltage corresponding to I_2, obtained elsewhere in the circuit and the resulting current is integrated in the simulator circuit for C to produce V_1. V_1 is inverted and used as one of the inputs to the L_1 simulator. Continuing the interconnection of elements in this manner produces all necessary input quantities for the component simulators and the only input needed is E_1.

It is unnecessary to write any differential equations in deriving the simulator circuit. The simulator has only as many energy-storage elements as the original circuit.

Mechanical Elements

Direct simulation techniques work also when deriving the analog computer road map for a network of mechanical elements. The three basic types of mechanical elements—masses, springs, and viscous damping devices—may be represented by corresponding analog computer circuits also shown in Figure 2.

A mass integrates the forces acting on it to produce velocity, and it may be represented by an electronic integrator and potentiometer. A spring may also be represented by an integrator and a potentiometer, with the relative velocity between its ends as the input, and the developed force as the output. Since the viscous damping device obeys a mechanical Ohm's law, relating velocity, force, and the damping coefficient, its operation may be simulated by a potentiometer as shown.

Figure 3 illustrates the method of assembling the basic analog elements to simulate a complete mechanical network. The most convenient method consists of first drawing the analog computer equivalents of the various elements, with their inputs and outputs labeled as shown, and then interconnecting them to form the complete diagram.

The resulting computer diagram is similar to the one for the simple electrical circuit, since the chosen mechanical network is an analog of the electrical network.

Conventional Methods

To illustrate the difficulties involved, Figure 4, 5, and 6 develop computer circuits for the same electrical network using the conventional differential-equation methods.

The differential equations that describe behavior of this circuit may be written in several different forms. Perhaps the most commonly used are the loop equations. These are written in terms of the mesh currents I_1 and I_2 and state that the sum of voltages around each loop is zero (see Figure 4).

Z_{11} and Z_{22} are the impedances of meshes 1 and 2 respectively. Z_{12} equals Z_{21} and is the impedance common to meshes 1 and 2.

A computer road map for the loop equations is derived in the conventional manner. The upper string of integrators deals with I_1 and the lower with I_2. The circuit requires four electronic integrators, although there are only two inductances and one capacitor, and hence three energy-storage elements, in the original electrical network.

Such a computer circuit usually gives erroneous results, because the extra integrator adds an extraneous root to the characteristic equation. It will be accurate only if the integrators are precisely matched.

For a simple circuit, such as the one under discussion, the computer road map can usually be inspected and rearranged to eliminate the extra integrator and give satisfactory results, but the entire process is time consuming and becomes very difficult as the complexity of the network to be simulated is increased.

Nodal Equations

The nodal equations for a network are statements that the sum of currents at any junction in the network is zero. The network used for the first example must be rearranged slightly, since expression in nodal form uses driving currents instead of driving voltages. In Figure 5, the current passing from the driving source through I_1 is designated as I_1, and the nodal points 1 and 2 are designated as shown.

Y_{11} and Y_{22} are the admittances connected to nodes 1 and 2 respectively. Y_{12} equals Y_{21} and is the admittance between nodes 1 and 2.

In Figures 4 and 5, p is the differential operator $\frac{d}{dt}$. Therefore, in Figure 4

$$pI = \dot{I} \text{ and } \frac{1}{p} I = \int I dt$$

and in Figure 5

$$pV = \dot{V} \text{ and } \frac{1}{p} V = \int V dt$$

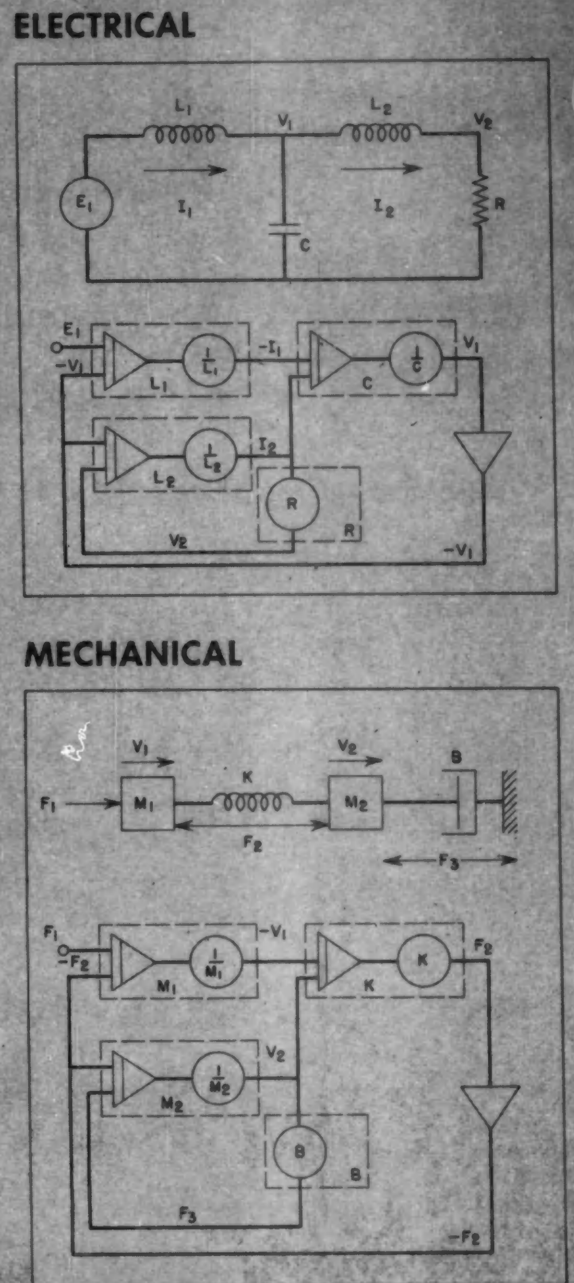
The nodal equations may be mapped in a computer circuit as shown in Figure 5. Here again, four integrators are needed and the same difficulty with extraneous roots arises as in the case of the loop equations.

Branch Currents and Nodal Voltages

A third method of deriving the circuit equations uses nodal voltages and branch currents. If these voltages and currents are defined as in Figure 6, the equations may be written by inspection.

The computer road map for solving these equations consists of only three integrators and one inverting amplifier. This circuit will give satisfactory results since the number of integrators is correct. It is less expensive to assemble since it requires less equipment.

...WHAT THEY DO

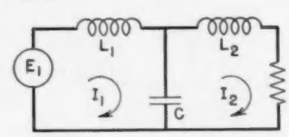


Direct simulation of analogous electrical and mechanical systems. Note that the same computer circuit merely assumes different analog quantities. Fig. 3

CONVENTIONAL METHODS...

NETWORK LOOP EQUATIONS

Circuit



General form:

$E_1 = Z_{11}I_1 + Z_{12}I_2$

$0 = Z_{21}I_1 + Z_{22}I_2$

Differential operator form

$E_1 = (pL_1 + \frac{1}{pC})\, I_1 - \frac{1}{pC}\, I_2$

$0 = -\frac{1}{pC} I_1 + (pL_2 + R + \frac{1}{pC})\, I_2$

Differential equations

$E_1 = L_1\dot{I}_1 + \frac{1}{C}\int I_1 dt - \frac{1}{C}\int I_2 dt$

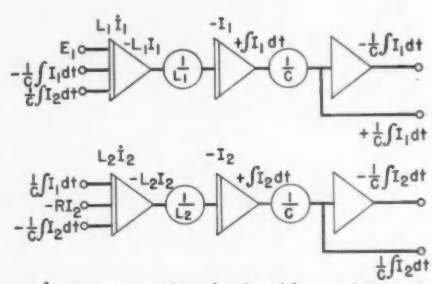
$0 = -\frac{1}{C}\int I_1 dt + L_2\dot{I}_2 + RI_2 + \frac{1}{C}\int I_2 dt$

Or

$L_1\dot{I}_1 = E_1 - \frac{1}{C}\int I_1 dt + \frac{1}{C}\int I_2 dt$

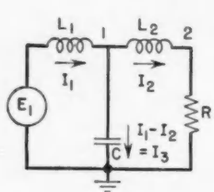
$L_2\dot{I}_2 = \frac{1}{C}\int I_1 dt - RI_2 - \frac{1}{C}\int I_2 dt$

Computer Diagram



"Road-mapping" these equations produces a computer circuit with one integrator more than there are energy-storage elements in the original circuit. Fig. 4

NETWORK NODAL EQUATIONS



$L_1\dot{I}_1 = E_1 - V_1$

$L_2\dot{I}_2 = V_1 - V_2$

$I_3 = I_1 - I_2$

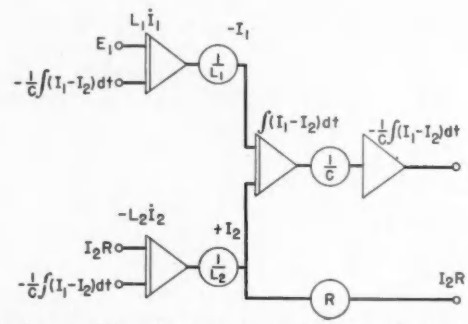
$V_1 = \frac{1}{C}\int I_3 dt = \frac{1}{C}\int (I_1 - I_2) dt$

$V_2 = I_2R$

Combined form

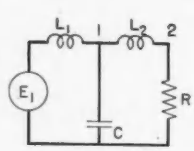
$L_1\dot{I}_1 = E_1 - \frac{1}{C}\int (I_1 - I_2)\, dt$

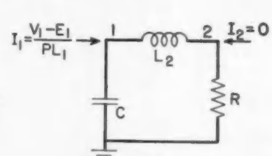
$L_2\dot{I}_2 = \frac{1}{C}\int (I_1 - I_2)\, dt - I_2R$



The nodal equations also require one integrator too many, which introduces an extraneous root and may cause instability. Fig. 5

BASIC KIRCHOFF-LAW EQUATIONS





Nodal equations

$I_1 = Y_{11}V_1 + Y_{12}V_2$

$I_2 = 0 = Y_{21}V_1 + Y_{22}V_2$

In differential operator form

$\frac{V_1 - E_1}{PL_1} = (PC + \frac{1}{PL_2})\, V_1 - \frac{1}{PL_2} V_2$

$0 = -\frac{1}{PL_2} V_1 + (\frac{1}{PL_2} + \frac{1}{R})\, V_2$

Differential equations

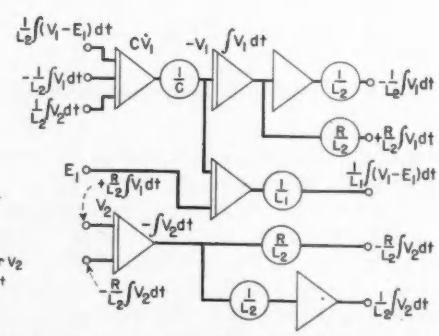
$\int \frac{(V_1 - E_1)}{L_1} dt = C\dot{V}_1 + \frac{1}{L_2}\int V_1 dt - \frac{1}{L_2}\int V_2 dt$

$0 = -\frac{1}{L_2}\int V dt + \frac{1}{L_2}\int V_2 dt + \frac{V_2}{R}$

Solving 1st equation for $C\dot{V}_1$ & 2nd for V_2

$C\dot{V} = \frac{1}{L_1}\int (V_1 - E_1) dt - \frac{1}{L_2}\int V dt + \frac{1}{L_2}\int V_2 dt$

$V_2 = \frac{R}{L_2}\int V_1 dt - \frac{R}{L_2}\int V_2 dt$



Nodal voltages and branch currents produce a circuit with the right number of integrators. Direct simulation saves even writing the equations. Fig. 6

Junctions of Like Elements

For networks that include junctions of three or more elements of the same kind, direct simulation becomes more difficult. Figure 8 shows a simple example of a network containing a junction of three inductances. If an attempt is made toward direct simulation involving the principles previously discussed, with an integrator for each inductance, and an integrator for the capacitor, some of the necessary input quantities for these elements cannot be obtained. This difficulty may be overcome by a special analog circuit for simulating the junction of the inductances as shown in Figure 7. The sum of the currents flowing to the junction is zero, and so the sum of their derivatives is zero.

Then $$\frac{V_1 - V_0}{L_1} + \frac{V_2 - V_0}{L_2} + \frac{V_3 - V_0}{L_3} = 0$$

or $$\frac{V_1}{L_1} + \frac{V_2}{L_2} + \frac{V_3}{L_3} = V_0\left(\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}\right)$$

Thus, the voltage at the junction, V_o is not dependent upon time and may be expressed in terms of the other voltages and the values of the inductances.

Solution of this equation in the first form by an analog computer gives a circuit having one potentiometer corresponding to each inductance and involving two more amplifiers than the number of inductances. This may be termed a "minimum-potentiometer" circuit since it uses a minimum number of potentiometers. Solution of the equation in the second form by the analog computer requires a circuit involving only one computing amplifier but requiring an additional potentiometer. This may be labeled a "minimum-amplifier" circuit. Choice of the proper circuit is discussed later.

The analog circuit for a junction of capacitances also derived is in Figure 7. The sum of currents flowing to the junction is set equal to zero. The currents are expressed in terms of time derivatives of the voltages across the capacitors. Integrating the resulting equation relates the voltage V_o to the voltages V_1, V_2, and V_3 without involving time as a variable.

These equations assume that the constant of integration, K, is zero. This assumption does not affect the use of the equations for an electrical network involving a junction of capacitors, since the initial value of V_o has no effect on the response of the rest of the circuit.

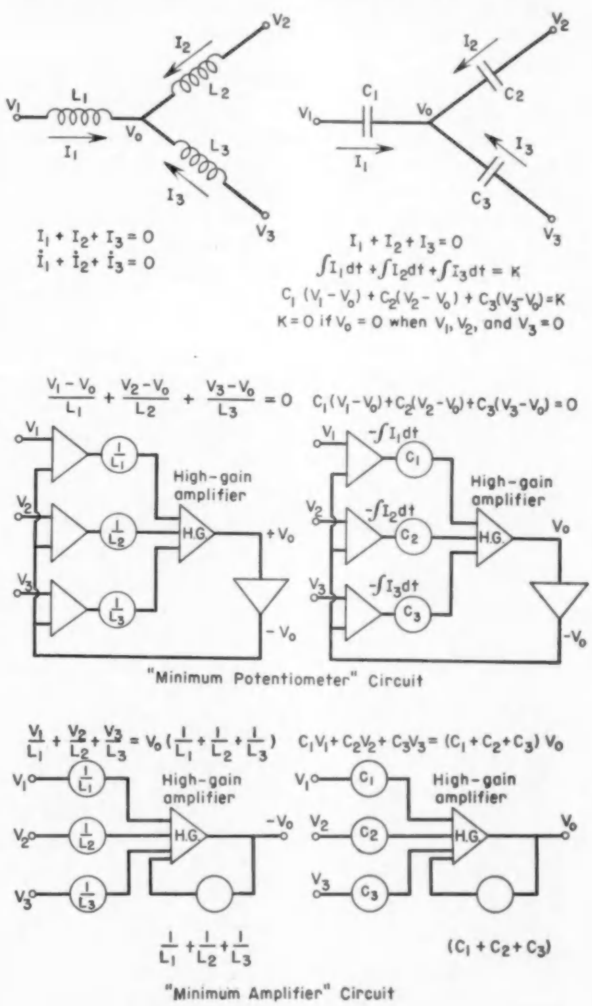
The junction of capacitors can be simulated by a minimum-potentiometer circuit or a minimum-amplifier circuit, with each circuit having the same advantages and disadvantages as the corresponding circuit for the junction of inductances.

The number of capacitances or inductances may be increased by adding more potentiometers and amplifiers to the minimum-potentiometer circuit, or more potentiometers and inputs to the single high-gain amplifier on the minimum-amplifier circuit.

Figure 8 illustrates the use of both types of computer circuit for solving a simple electrical network involving a junction of three inductances. Each computer circuit uses only three integrators. There is no integrator corresponding to L_1 since the current through L_1 is determined by the sum of the currents through L_2 and L_3. The behavior of the circuit can be completely described by a third order system of differential equations.

Either computer circuit gives valid solutions. Choice of which circuit to use depends upon the available equipment. The first circuit is preferable,

JUNCTIONS OF THREE OR MORE SIMILAR ELEMENTS



Number of elements may be increased by adding potentiometers and amplifiers to the "minimum-potentiometer" circuit, or potentiometers to the "minimum-amplifier" circuit. Fig. 7

because it offers greater operating convenience with only one potentiometer for each circuit element. If the number of available computing components is limited, the second circuit should be used because it needs fewer amplifiers.

The second circuit is much less convenient to operate. For example, if it were desired to change the value of L_2, three potentiometers would have to be reset in the second circuit but only one in the first circuit.

The computer circuits for a junction of capacitors may be used in a similar manner. An example is not given here, because such junctions rarely occur in actual electrical networks.

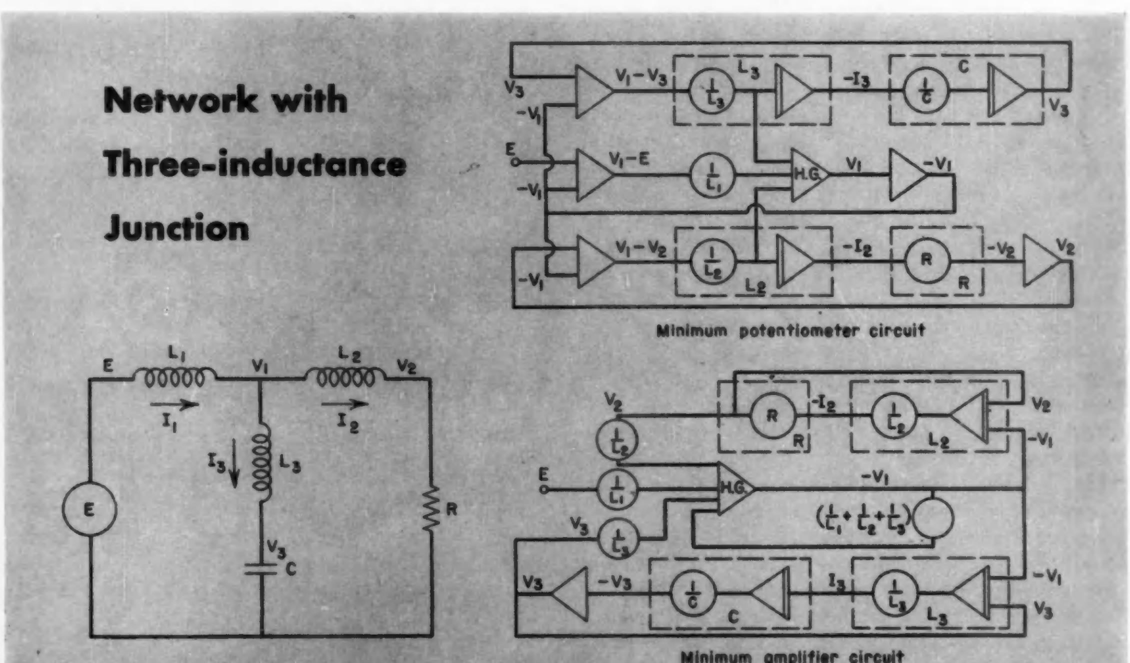
System Simulation

A common dc motor-generator speed control system is diagrammed in Figure 9. The electrical output of a dc generator, with shaft driven at constant speed, connects to the armature of the motor the speed of which is to be controlled. The field excitation for the motor is fixed. The motor shaft is mechanically coupled to a tachometer generator that produces an output voltage, E_t, proportional to the motor speed. This voltage is subtracted from a speed control voltage, E_s, and the difference, or error signal, controls the generator field voltage through a correcting network and an amplifier.

The generator field excitation determines the generator's output voltage, which in turn determines the motor's speed. Any difference between the tachometer voltage, E_t, and speed control voltage, E_s, makes the motor change speed to reduce the difference. Thus, the motor speed is determined by E_s. The correcting network can be simulated by the techniques already described.

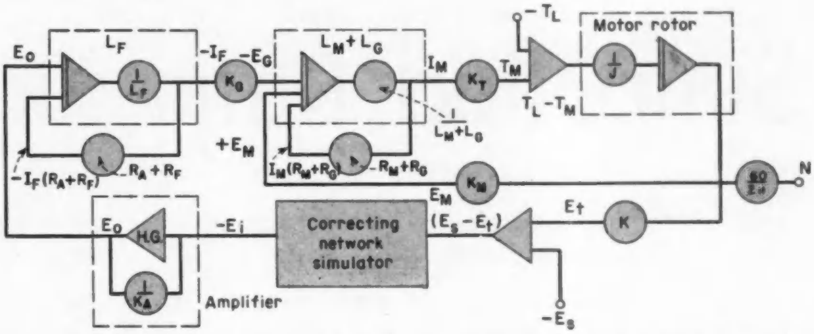
An analog computer circuit for directly simulating this system is shown in Figure 10. Starting in the upper left corner, the amplifier output voltage E_o, minus the voltage drops across the internal resistances of the amplifier and the generator field, is applied to a cascaded electronic integrator and potentiometer representing the field-inductance L_F. The output is an analog voltage representing the field current, $-I_F$. This is multiplied by a potentiometer set at the sum of the amplifier and generator field resistances to give the voltage drop across these elements. The field current analog voltage is also impressed on a potentiometer set at the generating constant K_G, of the generator. This gives an analog voltage corresponding to the emf of the generator.

In Figure 9, the electrical circuit between the generator and motor contains two series inductances, corresponding to the inductances of the generator and motor armatures, and two series resistances, representing the internal resistances of the motor and generator armatures.

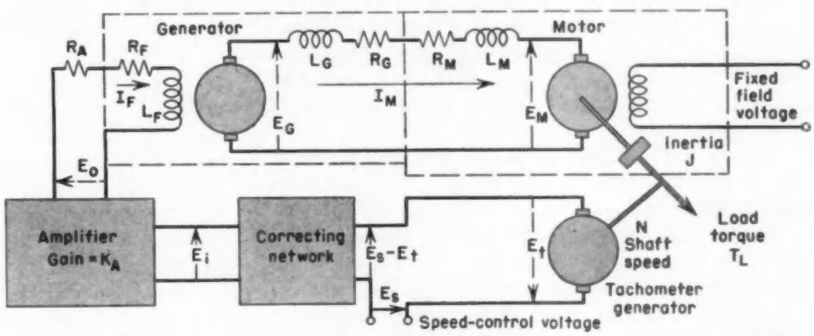


The "minimum-amplifier" circuit saves computing equipment, but the "minimum potentiometer" circuit is simpler to operate, having only one potentiometer for each component. Fig. 8

DIRECT SIMULATION OF A TYPICAL SPEED-CONTROL SYSTEM



Common dc motor-generator speed-control system demonstrates how easily direct simulation can be applied to more complex practical problems. Fig. 9



Computer diagram of the system of Figure 9. No equations have been written, and each component has computer elements independent of the others. The simulator circuit uses the minimum number of integrators. Fig. 10

The total voltage applied across the inductances alone is the generated voltage, E_G, less the motor's back emf, E_M, less the voltage drops across the resistors. Thus, feeding $-E_G$, E_M, and $L_M(R_M + R_G)$ into the integrator and potentiometer combination representing $(L_M + L_G)$ results in an analog voltage representing I_M at its output.

This quantity, I_M, is multiplied by a potentiometer set at $(R_M + R_G)$ to give one of the inputs to the integrator. It is also multiplied by the torque-constant of the motor, K_T, to give the motor's generated torque. The load torque, T_L, fed in externally, is subtracted from the generated torque to give the accelerating torque on the rotor. This accelerating torque is divided by the rotor's polar moment of inertia, J, and integrated with respect to time to give the rotor's angular velocity, ω.

The potentiometer set to the reciprocal of J and the integrator connected to it form an electronic analog of the rotor, with torque as the input and angular velocity as the output. The rotor angular velocity, ω, is multiplied by the proper constant K_M to give the motor's back emf, which is used as an input to the integrator for the $(L_M + L_G)$ circuit. It is also multiplied by the tachometer generator constant, K, to give the voltage generated by the tachometer generator. This voltage, E_t, is subtracted from the control voltage, E_s, in the operational amplifier as shown and the difference, or error voltage is passed to the correcting network simulator.

One of the main problems of a control system design is the correcting network. In actual practice, simulator circuits for various tentative network designs would be inserted in the space indicated, to be tested with the rest of the system. Since the network chosen can be simulated using the principles previously discussed, the correcting network simulator is not diagrammed. The output of the correcting network simulator is then amplified by the proper constant, K_A, to produce E_o. This is the input to the integrator representing L_F. Thus, the system is completely closed, and all needed internal quantities have been produced.

Direct simulation results in a minimum number of computing components, and so makes it relatively easy to simulate extremely complex networks.

LET'S KEEP IT FUNCTIONAL:

Simplified Ratio Control

Automatic treatment of water and sewage does not always demand high precision. Often the ratio of the two flows needs be held only within plus-or-minus 5 per cent. In such cases the cost of elaborate pneumatic or electronic ratio-control equipment is not justified. Read this article to learn the engineering design of simple and inexpensive flow-ratio control systems.

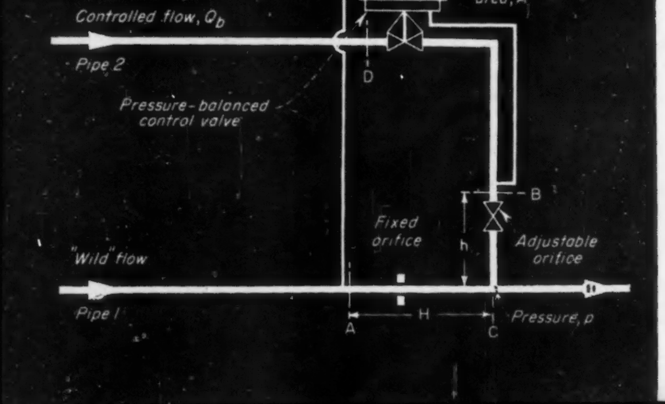
STANLEY LENOX, The Permutit Company

DESIGN OBJECTIVE: To maintain a definite ratio between the flow rates of liquids passing through two pipes.
SOLUTION: Insert an orifice in each pipe and keep the pressure drops across the two orifices equal. The flow through each orifice is proportional to its area. Therefore, as long as the areas are fixed, the ratio of the flows is constant.

CONTROL SYSTEM—DESIGN 1

Figure 1 illustrates the simplest control system. Pipe 1, carrying the "wild" flow, contains a fixed orifice plate whose size is discussed under "Control Accuracy." Pipe 2, which carries the controlled flow, is fitted with an adjustable orifice—usually an ordinary gate valve. Should Pipe 2 be oversized in anticipation of larger flows than those planned for immediate plant operation, the gate valve should throttle over a wide range.

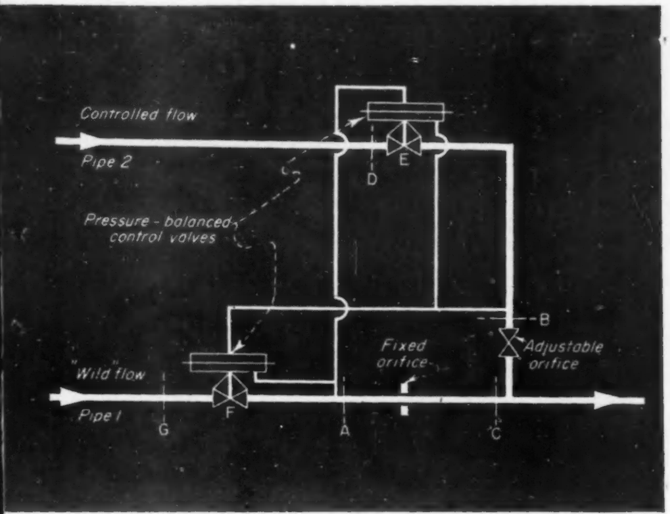
Flow ratio control system when the pressure at D is greater than the pressure at A for all flows. Fig. 1.



Pressure on the top of the diaphragm opens the pressure-balanced control valve and pressure on the bottom closes it. The liquids in both pipes are led directly to the valve diaphragm. This arrangement is satisfactory if the liquids do not corrode the diaphragm and casing. It has the substantial advantage that valve-stem packing and seal are eliminated. As a result, valve operation is almost frictionless. If either of the pipes contains a liquid which corrodes the valve topworks, the pressure from the appropriate pipe is transmitted to the valve diaphragm through an air or water purge. In case the liquid in Pipe 2 is corrosive, or if there is a possibility of corrosive liquid from Pipe 1 getting back into Pipe 2, a valve-stem seal is necessary.

The pressures at A and B are equal when the control valve is not moving. An increase in the flow in Pipe 1 increases the pressure at A, above the pressure at B, opening the control valve until the two pressures equalize and thus restore the flow ratio. Conversely, the pressure at B exceeds the pressure at A when the flow increases in Pipe 2, moving the valve toward the closed position until the flow in Pipe 2 is reduced sufficiently to restore the ratio.

Note that in order for the control valve to function, the pressure in section *D* must be greater than the pressure at A over the entire flow range. Should the pressure at A exceed that in *D*, the valve opens wide and the system fails to operate. In general, the greater the minimum pressure differential between D and A, the smaller the control valve need be.



Two valves are required to maintain ratio when the pressure at D is not necessarily always greater than the pressure at A. Fig. 2.

If minimum pressure drop is too low, losses due to friction in Pipe 2 are significant compared to loss across control valve, reducing control sensitivity.

Size the control valve by computing both the minimum and maximum C_v values* required. In the computations, use the pressure differentials between *D* and *A*. Calculate the maximum C_v at minimum pressure differential and at a flow rate which is 25 per cent greater than the maximum design flow rate. Calculate the minimum C_v at maximum pressure differential and minimum design flow rate. Select a valve with a C_v equal to or greater than the required maximum C_v. Check the valve rangeability* to be sure that the minimum C_v requirement is met. Double-ported valves with an equal percentage characteristic provide stable control. And they offer a rangeability of 20 to 1 or more.

The control system described has been used in Zeolite water-softening plants where it is sometimes desirable to treat only a portion of the water supply, blending raw water with treated water at the plant effluent. Pipe 1 usually carries the treated water; Pipe 2 carries the bypassed raw water. The system is useful for the feeding of chemicals in proportion. A typical example is the blending of hydrogen zeolite and water softened with sodium zeolite.

CONTROL SYSTEM—Design 2

Sometimes it is impossible or undesirable to keep the pressure in Pipe 2 higher than the pressure in Pipe 1 under all flow conditions. Consider, for example, the case when raw water is bypassed around a Zeolite softening plant to remove iron. When the filter located in Pipe 2 is dirty, the pressure in Pipe 1 is greater than the pressure in Pipe 2. If it is impractical to introduce additional head loss into Pipe 1, use the system shown in Figure 2. Here there are two valves. An increase in the pressure at *B* above the pressure at *A* tends to close valve *E* and open valve *F*. Both actions restore the flow ratio. Assume, however, that the pressures at *D* and *G* are such that, with both control valves wide open, the pressure at *A* exceeds that at *B*. Valve *E* stays open, but valve *F* throttles and restores the ratio. Similarly, if pressure at *B* is greater than at *A* with both valves open, *F* remains open, but *E* throttles. Regardless of upstream pressures, at least one of the valves functions to maintain the desired flow ratio.

Size the valves in Figure 2 by computing the required C_v's at design flow and at the following pressure drops:

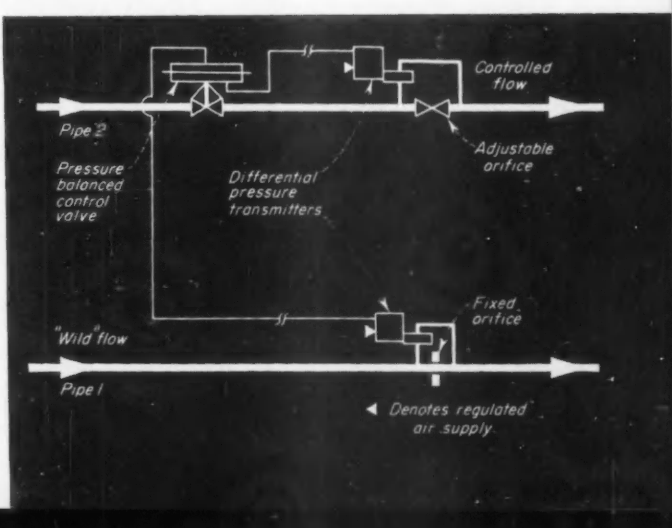
- For valve *F* use the maximum pressure at G less the minimum pressure at *B* with valve *E* wide open.
- For valve *E* use the maximum pressure at *D* less the minimum pressure at *A* with valve *F* wide open.

If either liquid is corrosive, it is necessary to seal both valve stems and to purge the pressure-transmitting lines.

CONTROL SYSTEM—Design 3

In both systems discussed so far, the flows join downstream of the orifices. There are many cases in which the streams do not merge, and yet the principles of the simple systems discussed provide adequate control accuracy at reasonable cost. A case in

A system for controlling the ratio of two flows which do not mix. Fig. 3.

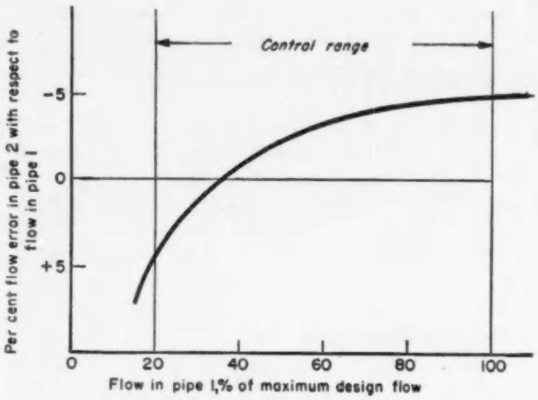


*DEFINITIONS

C_v is defined as the gpm of water at 60 deg F that a differential pressure of 1 psi will force through a fully opened valve. It is calculated by:

$$C_v = Q\sqrt{\frac{G}{\Delta P}}$$

where Q = flow in gpm, G = specific gravity, P = pressure drop across valve. Rangeability is the flow range over which a valve will control flow in response to forces applied to the diaphragm or by the operator. It is the ratio between the maximum and minimum C_v's at which the valve will control.



The plot of controlled flow error versus "wild" flow is parabolic. Maximum positive error is balanced against maximum negative error by selecting the conditions of minimum flow. Fig. 4.

point is the splitting of a plant feed into two streams, one of which is processed under pressure and the other at atmospheric pressure. Figure 3 shows the system. Any of several inexpensive differential transmitters on the market will provide signals and actuating pressures. Selection of the differential-pressure-transmitter range is governed by the maximum differential across the orifices. Liquids which would corrode the differential-pressure-sensing mechanisms are retained by air or water purges. Because the transmitters' output is limited to 20-psi-to-25-psi, it is necessary to use valve stem seals to prevent the liquids from backing into the pneumatic lines.

CONTROL ACCURACY

It may appear that these systems are free from error and that the pressure drops across the orifices are unimportant. This would be true if the moving valve parts were weightless and if there were no stem friction. To evaluate the effect of valve weight on system accuracy, consider Figure 1 and let:

SAMPLE CALCULATION

A plant is supplied directly from well pumps having a capacity of 500 gpm. Demand varies from 100 to 450 gpm. In order to reduce the iron content to the point where it will not be objectionable, 70 per cent of the supply is treated in iron-removal filters, the other 30 per cent being bypassed. The two streams are blended after treatment. At 70 gpm the estimated pressure loss through the filters and auxiliary equipment is 2 psi minimum (when filters are clean), and 4 psi maximum (when filters are dirty). At 315 gpm these losses are 4 psi and 15 psi. The permissible error in the bypassed flow is $\pm$ 5 per cent. Since the initial pressure in both lines is the same (from the well pump), the difference in pressure between the bypass line and the treated water line just upstream of the control equipment is the pressure loss through the filter. The situation corresponds to that shown in Figure 1.

The valve is sized by computing the required maximum and minimum C_v values as follows:

maximum C_v based upon 125 per cent of 135 gpm and a pressure drop of 4 psi

$$C_v = \frac{1.25 \times 135\sqrt{1}}{\sqrt{4}} = 84.4$$

minimum C_v based upon 30 gpm and 4 psi pressure drop

$$C_v = \frac{30\sqrt{1}}{\sqrt{4}} = 15$$

required rangeability = 84.4 ÷ 15 = 5.6

A check of valve manufacturers' data shows that a 3-in. valve is required. Assume that the moving parts of this valve weigh 15 lb and the effective diaphragm area is 110 sq. in.; W/A = .137.

The required orifice loss can now be computed by cut-and-try by Equation 3 to meet the specification:

maximum allowable error at minimum flow, − 5 per cent
maximum allowable error at maximum flow, + 5 per cent

If the system is adjusted at 100-gpm flow through the filters:

R minimum = .70 $\quad$ R maximum = 3.16

$$\text{at minimum flow } H_o = .137\,\frac{(1.05)^2 - \dfrac{1}{(.70)^2}}{1 - (1.05)^2} = 1.29 \text{ psi}$$

$$\text{at maximum flow } H_o = .137\,\frac{(.95)^2 - \dfrac{1}{(3.16)^2}}{1 - (.95)^2} = 1.10 \text{ psi}$$

Because the two values of H_o do not agree, a second trial is made, based upon an initial flow of 95 gpm through the filters.

R minimum = .738 $\quad$ R maximum = 3.32

$$\text{at minimum flow } H_o = .137\,\frac{(1.05)^2 - \dfrac{1}{(.738)^2}}{1 - (1.05)^2} = 1.02 \text{ psi}$$

$$\text{at maximum flow } H_o = .137\,\frac{(.95)^2 - \dfrac{1}{(3.32)^2}}{1 - (.95)^2} = 1.11 \text{ psi}$$

Based upon these two trials it is safe to say that if the system is initially adjusted at 95 gpm flow through the filters and the fixed orifice is sized to produce an unrecovered loss of 1.12 psi at this flow, the control error will be within the plus or minus 5 per cent required.

p = common pressure at C, psi
H = unrecovered pressure drop across fixed orifice, psi
h = unrecovered pressure drop across adjustable orifice, psi
W = weight of moving parts of valve (stem, discs, diaphragm plates, etc.), lb.
A = effective valve diaphragm area, sq. in.
X = per cent flow error in Pipe 2 with respect to flow in Pipe 1.
Q_b = flow in Pipe 2, gpm
o = subscript referring to conditions in system as initially adjusted ($X = 0$)
r = subscript referring to conditions in system when flow in Pipe 1 is R times flow at condition "o"

When the valve is not in motion, the following relationship exists:

$$(p + h)A = (p + H)A + W$$

or

$$= H + W/A \qquad \text{Eq. 1}$$

from basic hydraulics Q_b is proportional to $\sqrt{h}$;
and $H_r = H_o R^2$
therefore Q_{bo} is proportional to $\sqrt{H_o + W/A}$
and Q_{br} is proportional to $\sqrt{H_o R^2 + W/A}$

The error in flow in Pipe 2:

$$X_r = \frac{RQ_{bo} - Q_{br}}{RQ_{bo}}$$

$$= \frac{R\sqrt{H_o + W/A} - \sqrt{H_o R^2 + W/A}}{R\sqrt{H_o + W/A}}$$

$$X_r = 1 - \sqrt{\frac{H_o + \frac{1}{R^2} W/A}{H_o + W/A}} \qquad \text{Eq. 2}$$

ANALYTICAL CONCLUSIONS:

- An increase in W/A causes an increase in the control error.
- An increase in H_o reduces the error.

Then, for greatest accuracy, the fixed orifice should be sized for the largest permissable pressure drop, and the valve should have the lowest possible ratio of weight of moving parts to diaphragm area.

By properly selecting the initial adjustment of the system (subscript "o" in the analysis), the error over the useful flow range is always positive, or it is always negative, or it can be balanced so that negative error at low flows equals positive error at high flows.

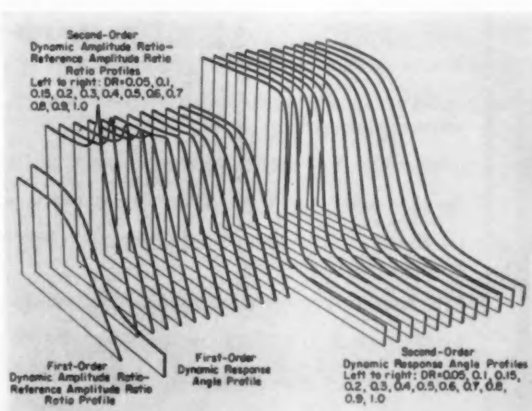
A typical curve of control error versus flow is shown in Figure 4. The system has been set up for balanced positive and negative errors. Because the curve is parabolic, it is necessary to adjust the system initially at some point near the lower end of the flow range. The location of the point varies with the required flow range. Trial and error solutions of Equations 2 and 3 are the easiest way to compute the value of the point.

When the permissable error is known, Equation 2 is rewritten to determine the required orifice pressure loss:

$$H_o = \frac{W}{A}\left[\frac{(1 - X_r)^2 - \frac{1}{R^2}}{1 - (1 - X_r)^2}\right] \qquad \text{Eq. 3}$$

TOOLS OF THE TRADE

Templates Help Plot Frequency Response



Control-systemengineers should know about a set of Plexiglas templates manufactured by Computing Aids, Cambridge, Mass.

These templates are precision-cut profiles of first- and second-order steady-state sinusoidal frequency-response functions. There are 26 profiles to the complete set, each cut to the same scale as follows: The log of the amplitude ratio as a function of the log of the frequency–2.50 in. per loru, 2.5 in. per decile, .125 in. per decibel; The dynamic response angle (or phase angle) as a function of the log of the frequency–1.0 in. per 20 degrees, 2.50 in. per loru, 2.50 in per decile.

Each profile has straight sides at right angles, respectively parallel to the coordinate axes of the curve representing the characteristic.

Drawing from "Instrument Engineering," Vol. II, Draper, McKay, and Lees, McGraw-Hill Book Co., Inc., New York.

31 Ways to Multiply

HOW TO PICK THEM
HOW TO USE THEM

Here is a roundup of important analog multipliers—mechanical, electromechanical, and electronic. The author originated the classification in the table below.

SIDNEY A. DAVIS, Servomechanisms, Inc.

Table I—THESE ARE THE 31 MULTIPLIERS

WAY NO	PRINCIPLE OF OPERATION	SEE FIG. NO.	REFERENCE	
1	Resistive pot — voltage proportional to product of input voltage and shaft rotation.	1(A)		DIRECT • TYPE I
2	Inductive pot — voltage proportional to product of input voltage and shaft rotation.	1(B)		
3	Induction pot — voltage proportional to product of input voltage and shaft rotation.	1(C)		
4	Self-balancing bridge — output angular position proportional to product of two shaft positions divided by third.	2		
5	Microsyn torque generator — output torque proportional to product of two input currents.	3(A)		
6	Microsyn torque generator with pickup device — output indication proportional to product of two input currents.	3(B)		
7	Microsyn torque computer — output voltage proportional to product of two input currents.	3(C)		
8	Separately excited dc motor — output torque or acceleration proportional to product of field strength and armature current.	4(A)		
9	Induction generator — output voltage proportional to product of input voltage and speed.	4(B)		
10	Two-phase induction motor — stall torque proportional to product of phase voltages.	4(C)		
11	Two-phase induction machine — output voltage proportional to product of dc input on one phase and shaft acceleration.	4(D)		
12	Pulse generator — average pulse proportional to product of input voltage and angle.	5		
13	Vacuum tube — output voltage proportional to product of two input voltages.	6(A)	a	
14	Cathode follower — output voltage proportional to product of two input voltages.	6(B)	a	
15	Vacuum tube — plate current proportional to product of two grid voltages.	6(C)		
16	Three-dimensional cam — output displacement proportional to product of input displacement and input rotation.	7		
17	Mech. multiplier — displacement proportional to product of two input displacements.	8	b	
18	Linkage multiplier — displacement proportional to product of two input displacements.	9	b	
19	Pulse generator circuit based on a law of probability — output voltage proportional to product of two or more input voltages.	10	a	

ANALOG COMPUTING circuits multiply either directly or indirectly. Multipliers with an output linearly related to each of two inputs can be further classified as type I direct multipliers. An example is the ordinary linear potentiometer, in which the output voltage is proportional to the product of the input voltage and shaft rotation.

Type II direct multipliers perform the mathematical operation in two distinct steps. In the first step, the system is adjusted to correspond with one of the multiplying variables. This proportionately regulates the transmission characteristics of the coupled system to the second variable. An example is a straight servo multiplier, which balances the output of a feedback potentiometer against one of the input variables. The shafts of the feedback and output potentiometers are mechanically connected to rotate together. Thus the transmission of the output potentiometer is proportionately regulated by the adjustment of its shaft position so that its output voltage represents the product of the two input voltages.

In addition to these direct methods, multiplication can also be performed indirectly as a sequence of other operations. As shown in Table I, indirect multiplication can use logarithmic, integral, or squaring techniques.

The specific form of multiplier in a given application depends on the choice of medium. It can be mechanical, electromechanical, chemical, thermal, electrical, etc. It can depend on the Hall effect, the Gauss effect, or other specialized phenomena. It can operate on ac, dc, pulses, root-mean-square values, instantaneous values, and others. Although these variations may alter the hardware of the computer, the multiplier operation will fall in one of the basic categories discussed above.

Which Multiplication Method?

The selection of the optimum multiplier involves a thorough knowledge of the system and the mechanics of multiplier operation. Usually the most important requirement is accuracy. In multiplier operation this is specified as the error in the product divided by maximum multiplier output. When the input is varying rapidly, accuracy specification also

WAY NO.	PRINCIPLE OF OPERATION	SEE FIG. NO.	REFERENCE	
20	Basic schematic — input proportional to product of two outputs divided by third.	11(A)	c	TYPE II
21	Push-pull circuit, control elements can be thermal, magnetic, etc. — output voltage proportional to product of two input voltages divided by third.	11(B)		
22	Servo multiplier — output voltage proportional to product of two input voltages.	12		
23	Strain-gage bridge — output voltage proportional to product of two input voltages.	14	d	
	LOGARITHMIC — $\log C = \log A + \log B$			INDIRECT
24	Logarithmic requiring antilogarithm generator — form of inputs and product depends on type of component parts.	15		
25	Logarithmic using feedback instead of antilogarithmic generator — form again depends on component parts.	16		
26	Logarithmic with added positive constants to permit zero and negative values of input — form again depends on component parts.	17		
27	Logarithmic using semi-conductor elements — output voltage proportional to product of two input voltages.	21	a	
	SUM OF INTEGRALS — $C = \int A dB + \int B dA$			
28	Summing integrals — form of inputs and product depends on type of component parts.	19		
29	Integral summation technique using electromechanical rotating components — output voltage proportional to product of two input shaft angles.	22		
	SQUARING — $C = \frac{1}{4}\,[(A + B)^2 - (A - B)^2]$			
30	Square-law multiplier — form of inputs and product depends on type of component parts.	18		
31	Square-law multiplier using thyrite elements — output voltage proportional to product of two input voltages.	24	e	

Table II

CONSIDER THESE FACTORS

a. Accuracy, calibration, and drift as required by application.
b. External requirements such as reliability, flexibility, and equipment economy.
c. Types of inputs and outputs and ease of integration with remaining elements of system.
d. Medium used in multiplication such as heat, complex waveforms, and mechanical motions.
e. Basic mathematical foundation such as direct multiplication, the use of logarithms or squaring techniques.
f. Relative independence of nominal shifts in line frequency, voltage, and harmonic content. This characteristic is mandatory in precise electrical systems.
g. Speed of response of output to rapidly varying inputs.
h. Range of input variables, with specific reference to zero and negative values. The maximum unsaturated output.
i. Freedom from noise in multiplier output; especially when unit is included in a feedback system, such as in application to problem of division. Noise includes not only such random quantities as pickup and thermal noise, but also harmonics that may be intrinsic in the output because of nonlinear operation.

should include complete dynamic response errors.

After accuracy, the next consideration is the overall reliability and equipment economy of a multiplier when it is integrally designed into a computing system. Although a dc multiplier may have many superior features, its use in an ac system might be undesirable because of the additional modulators and demodulators that are required. As another example, a mechanical computer for generating the function x sin y normally requires a resolver to generate sin y from y and a multiplier to obtain the final product. This might better be done with an electromechanical resolver that multiplies and generates the sine function in one unit, notwithstanding the extra mechanical-electrical conversion equipment required.

In some multipliers the input is isolated from the output. Where changes in the nature of the variable are desirable, this type can also serve as a transducer.

Usually multipliers based on vacuum tubes have the highest speeds of response, although many tubes are normally required to obtain high accuracy. Fast, accurate electronic multipliers usually operate by the controlled timing of pulses that act to saturate the output tubes. This minimizes the importance of most of the tube characteristics so that tube aging and matching can more or less be neglected. Rapid response is characteristic also of semi-conductor multipliers. But controlling and matching the characteristics of these highly temperature-sensitive devices is difficult.

Table II summarizes these and other factors involved in selecting the proper multiplier.

Specific Multiplying Devices

The following material illustrates and describes a variety of multiplying devices organized in accordance with the classification in Table I. Each group in turn is subdivided according to the media used in performing the multiplication—mechanical, electrical, thermal. Often the classification of a multiplying device will depend on viewpoint.

In many of the devices, combinations of variables other than those shown can be used by incorporating transducers to convert from one form of energy to another.

An additional section discusses the application of multipliers to types of computing operations other than pure multiplication.

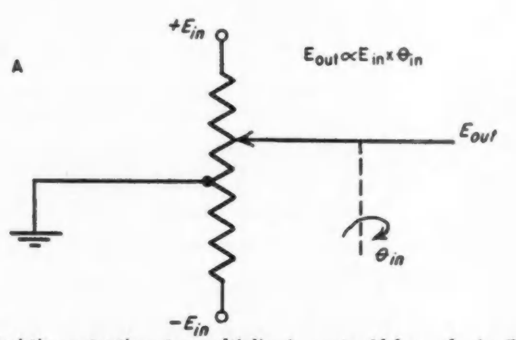
DIRECT MULTIPLIERS—Type I

As stated previously, a linear potentiometer is a simple example of this type of direct multiplier. Where both inputs must be electrical (a common situation) a device such as a special multi-grid, controllable-gain vacuum tube can be substituted. Proper choice of tube and operating bias, can insure accuracy of the order of 95 per cent, although calibration must be included for tube aging and replacement. An ordinary linkage multiplier is another example of this type of device.

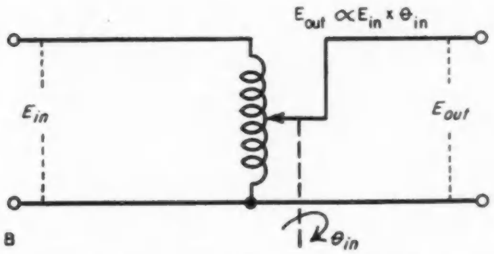
As a general rule, type I direct multipliers depending on regulated gain or transmission have low accuracy. The ordinary potentiometer is an exception.

Figures 1 through 6 show typical electrical and electromechanical multipliers in this classification.

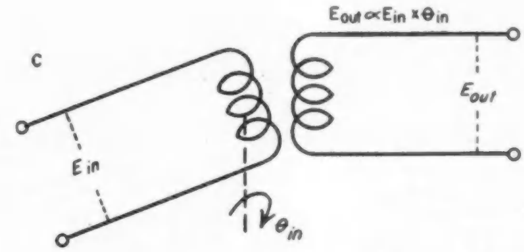
A



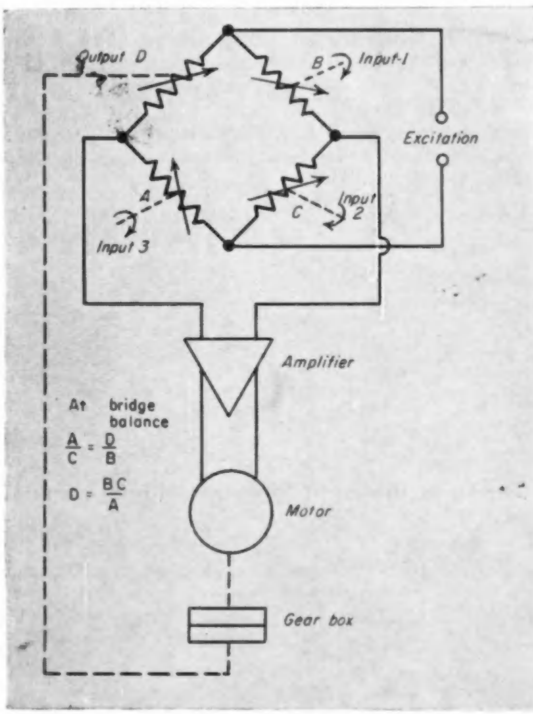
Resistive potentiometer multiplier is most widely used. Available with error as small as 0.01 per cent. Integrates with other parts of electrochemical computers. Fig. 1A



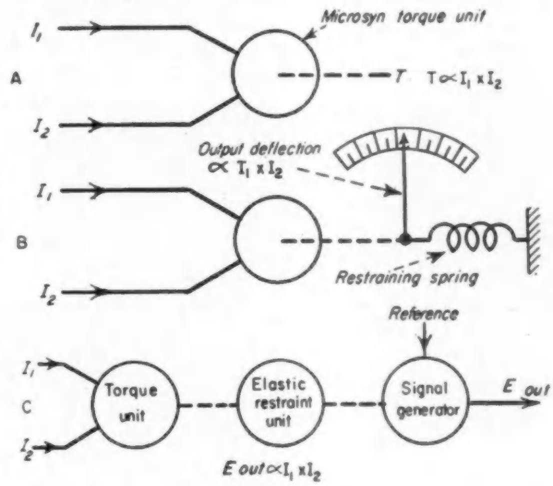
Inductive potentiometer multiplier. Available with error as small as 0.1 per cent. Usable only in ac systems. Unit can often be cascaded without isolation transformers. Fig. 1B



The induction potentiometer multiplier is available with error of 0.06 per cent. Considerable auxiliary equipment is required for compensation, but unit has almost infinite life. Fig. 1C



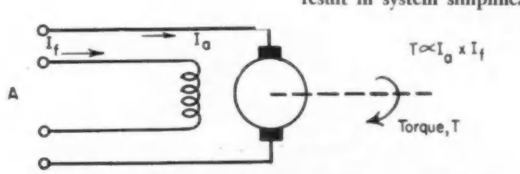
The self-balancing bridge is convenient for simultaneous multiplication and division of three variables where the inputs are available as shaft rotations. Accuracies are of the same order as those of the basic potentiometers. Fig. 2



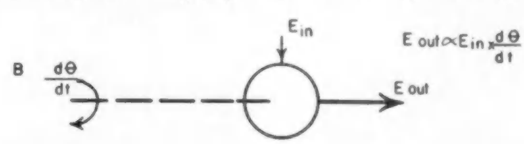
Torque Units for Multiplication. Fig. 3

(A)—The microsyn torque generator develops a torque proportional to product of two currents with error of 0.1 per cent.
(B)—By coupling to an elastic restraint member and a pickup device (pointer), it is possible to develop a useable indication output torque. It is similar to a wattmeter.
(C)—Microsyn torque computer for the multiplication of voltages. Microsyn units are of three varieties: the torque generator shown in (A) and (B), an elastic restraint unit that behaves like a linear spring having adjustable constants, and the signal generator that develops an output proportional to deflection. These units, when all mounted on a single set of low-friction bearings, are a common form of multiplier in gyroscopic systems. Accurate to within 0.1 per cent.

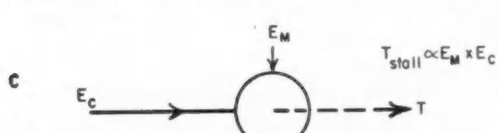
Four rotating components that are inherently capable of multiplication. This feature can result in system simplification since separate multiplying devices are not required. Fig. 4



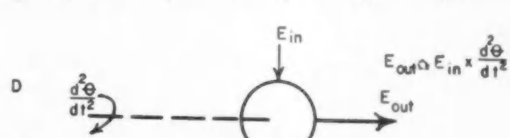
(A)—Torque or acceleration of separately excited dc motor is proportional to product of field strength and armature current.



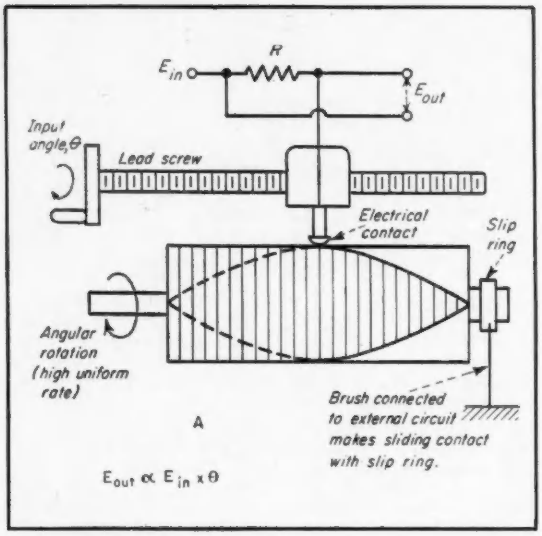
(B)—An induction tachometer generates an output voltage proportional to the product of input voltage and speed.

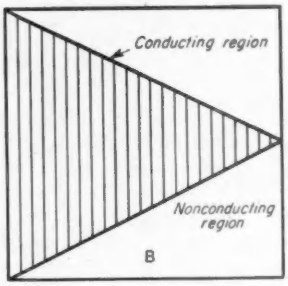


(C)—The stall torque of a two-phase induction motor is proportional to the product of the phase voltages.

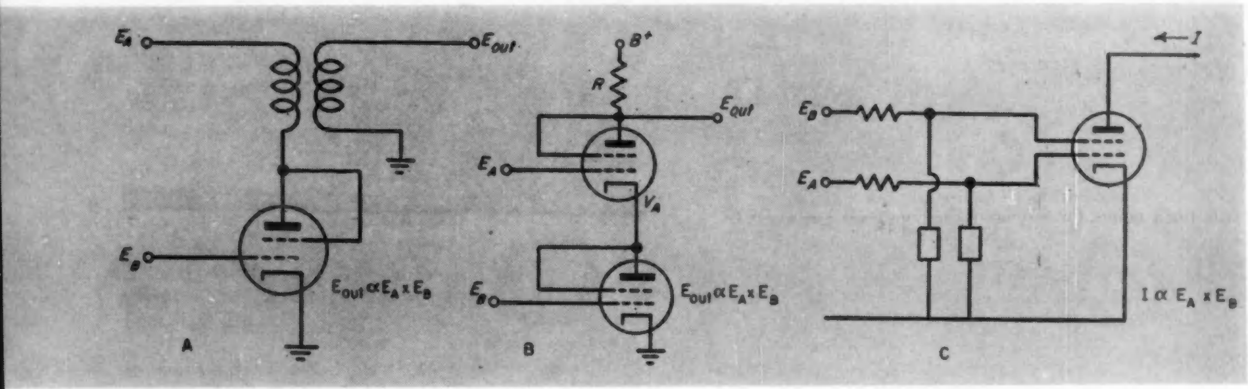


(D)—Induction machine develops output voltage proportional to product of dc input and shaft acceleration.





Multiplier generating pulsed output. Average value of pulse is the product of input voltage and input shaft angle. The output circuit draws current through *R* only when the electrical contact is on the conducting area. Area is a linear function of input angle. A photoelectric pickup can minimize wear. (B) shows a developed view of rotating cylindrical surface. Fig. 5.



(A)—Approximate vacuum tube multiplier. Operation is satisfactory for only a narrow range of variables.

(B)—Cathode follower circuit similar to that shown in (A). When the voltage V_A becomes approximately equal to E_A, the current through *R* varies as the product E_A times E_B.

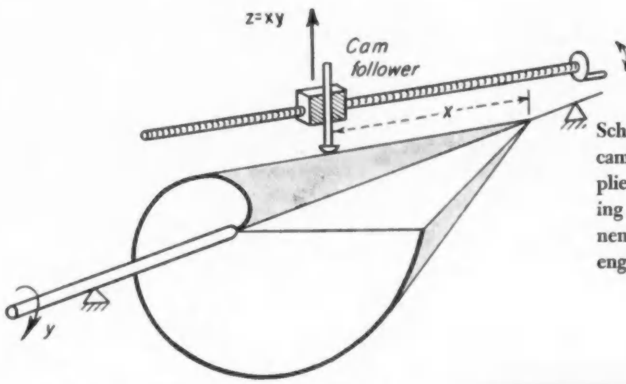
(C)—With some tubes, low-accuracy multiplication can be achieved because of the proportional relationship between plate current and either of two grid currents.

VACUUM TUBE MULTIPLIERS. FIG. 6

MECHANICAL MULTIPLIERS

In systems where the variables are in the form of displacements or shaft rotations, mechanical devices can be used for multiplication, often reducing the need for auxiliary equipment. Well designed linkages are compact and reliable. But they are hard to design accurately and need many precisely machined links. Although not as clearly standardized as electromechanical or electronic components, their suitability in certain situations often permits substantial simplification and economy.

Although a large variety of mechanical multipliers are available, those discussed in this section fall in the direct multiplication type I class, Figures 7 through 9. Indirect linkage multipliers that use logarithms or squaring functions have been developed to give fractional per cent accuracies. Often linkages are combined with rotating electromechanical components and other transducers for direct and compact problem solutions. Table III lists design and performance criteria for linkage multipliers.



Schematic of a three-dimensional cam for use as a mechanical multiplier. Improvements in manufacturing techniques have made components such as this available to the engineer. Fig. 7

Table III—DESIGN AND PERFORMANCE FACTORS FOR LINKAGE MULTIPLIERS

ACCURACY Most accurate units are usually the most complex mechanically. Errors can be divided into the inherent class *A* errors, and the class *B* errors derived from machinery tolerance or strains in the links.

NATURE OF VARIABLES Inputs should be available as displacements or rotations. Care should be taken to select the most convenient form of mechanical output.

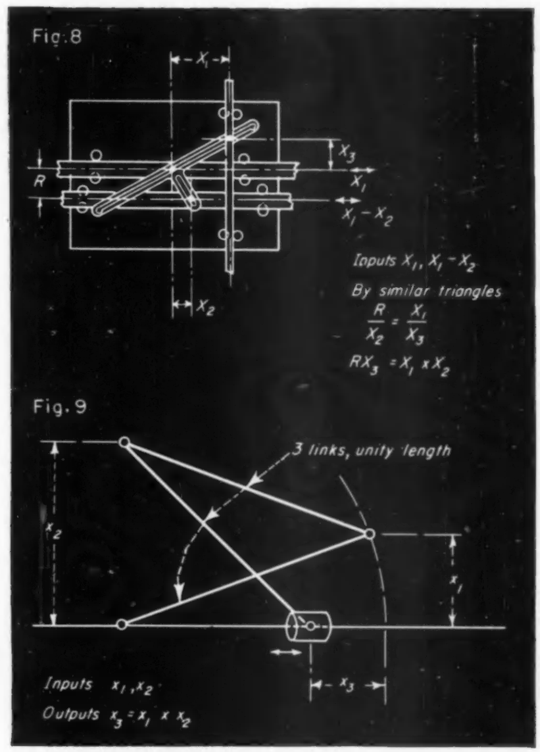
RANGE OF MOTION Theoretical accuracy is usually maximum for limited mechanical motion. However, small motions mean close tolerances and fits and minimum backlash.

FRICTION Close pivot tolerances required for precise motions increase friction. The mechanical advantage at the pivot points for various linkage positions can result in increased frictional forces reflected to the inputs and high mechanical strains in some of the links.

INERTIA Because linkage geometry is a function of the input variables, input inertia is in itself a variable. Inertial effects are highest in accurate units where large motions and heavy links are required.

AMBIGUITY Frequently there are ambigious settings of the links in a given constrained system, only one of which is suitable for computing. Spring mechanisms and limit stops can be used to avoid these erroneous settings.

SERVO DRIVE If the linkage is being driven by a servomechanism, variable inertia and friction become important factors affecting dynamic response and stability.



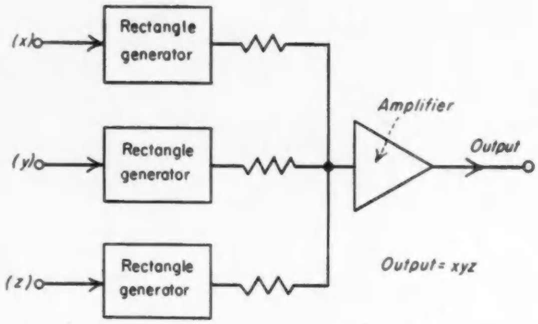
Mechanical multiplying based on the proportionality property of similar triangles. Fig. 8.

An approximate bar linkage multiplier. Simple and compact, it has an error of one per cent for input values up to 0.2. More complex linkages are required to obtain higher accuracies over wider ranges. Fig. 9.

WAVEFORM MULTIPLIERS

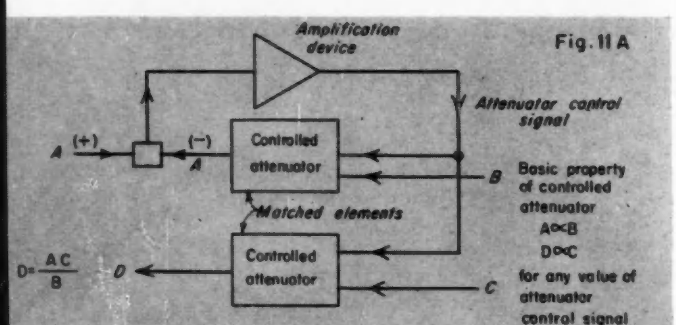
Many multipliers perform operations on periodic waveforms. The accuracy of these depends on the accuracy of the waveform generation and timing. Frequently many tubes are used, especially where fractional per cent accuracy is required. Although multipliers have been developed that minimize the effects of tube characteristics, others require frequent recalibration to compensate for tube aging and changes in filament voltage. Often tubes must be specially selected to insure highest accuracy.

A basic method is to vary the amplitude and duration of a rectangular waveform. If the base of the rectangle is held at zero potential, the average or integral of the waveform is proportional to the product of amplitude and duration. Computers using this principle have been built with errors of 0.2 per cent or less of maximum output. However, the inputs cannot go through zero. Triangular waveforms can be used similarly. An extension of this method, based on the application of a law of probability, is described in Figure 10.

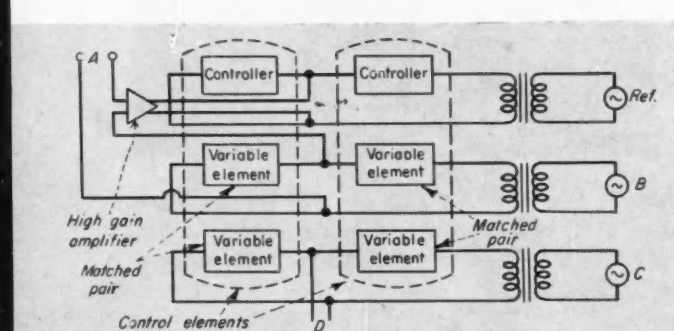


The generators produce rectangular pulses with width proportional to the magnitude of the input signal. The pulses generated by each have frequencies prime with respect to one another. Since pulse width is directly proportional to generator signal, the probability of the amplifier producing an output is proportional to the product of the input signals. This circuit is hightly accurate, but it will not handle negative inputs. Fig. 10.

DIRECT MULTIPLIERS—Type II



Generalized schematic of a type II direct multiplier. Fig. 11(A)



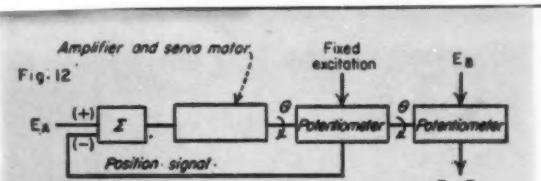
(B)—Specific version of multiplier shown in (A) with provision for including biasing reference signals in a push-pull circuit. This permits the introduction of sign-reversal characteristics. The reference voltage delivers balanced signals to the two controllers. Input *A* causes high-gain amplifier to increase signal to one controller and decrease it to other. This introduces corresponding unbalance in the bridges energized by *B* and *C*. The *B* bridge delivers an output equal to *A* because of the nulling function of the high-gain amplifier. The *C* bridge gives output *D* because it has the same unbalance.

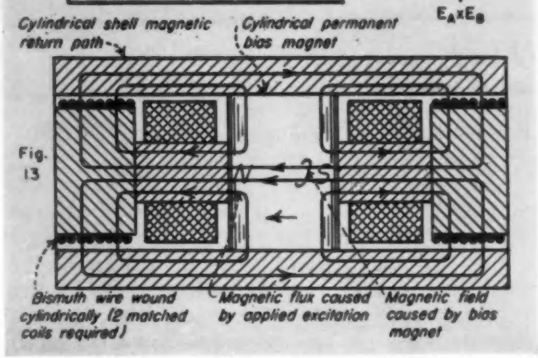
In this type multiplier one of the inputs is nulled against the output of an adjustable element, a. In the nulling process, a matched adjustable element, *b*, is brought to the same state as the first element. The outputs of the two adjustable elements must be linear with respect to the second input variable. Output of element *b* equals the product of its own input and the input bucking element a.

A schematic using electrical elements to demonstrate the fundamental multiplier arrangement based on the above definition is shown in Figure 11(A). This sort of system is potentially highly accurate, since the multiplying element requirements are not so severe as in the type I multipliers. In the latter, it is essential that the output be accurately proportional to each variable, whereas in type II multipliers the output need be proportional to only one variable. The relationship to the second variable can be quite flexible. Sensitivity to temperature, frequency, and voltage, theoretically at least, introduces no errors. All that is required is a precise match between the feedback element, a, and the coupled element, *b*.

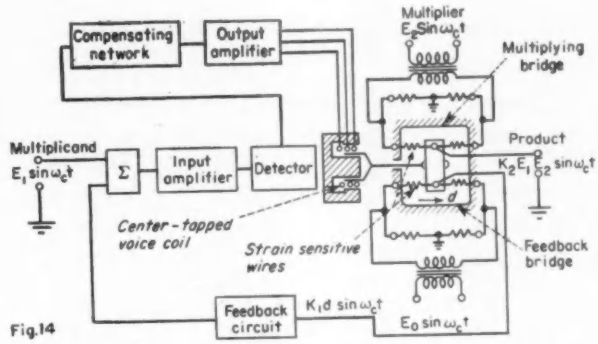
This feature can be seen in the multiplying servomechanism of Figure 12. As long as the two potentiometers are precisely matched, their linearity, temperature coefficient, and residual properties have no effect on the theoretical accuracy. Many low-accuracy type I multiplying elements will give much higher accuracy when the same basic element is used in a type II arrangement.

One unusual multiplier of this type is based on the use of thermal elements. Each element consists of two conductors in intimate thermal contact. One is a controlling heater made of a constant resistance material, such as Nichrome. The other variable element is made of a material having a high tem-





Conventional servo multiplier. Features are the requirement for matched potentiometers that need not be linear, and the inherent isolation between inputs and output. From another viewpoint this circuit can be classified as a type I multiplier with the servo acting as a transducer, converting an electrical input to a proportional shaft rotation. Typical time constants vary from 5 to 50 milliseconds with error of 0.01 per cent. Units are expensive and complex. Fig. 12.



Precision multiplier using strain gages actuated by an electromagnetically generated force. Error is about 0.1 per cent. Time constant is 1 millisec with a plus or minus 0.002 in. excursion of the strain gage armature. Fig 14

Magnetic circuit designed to apply controlled fields to bismuth wire for use in a multiplier circuit. Fig. 13

perature coefficient of resistance, such as nickel. By controlling the current in the heater it is possible to control the resistance of the heated element. Units have been designed with basic time constants in the order of 100 milliseconds; however, overall system response is more rapid because of the loop gain factor of the amplifier circuit.

This system suffers from several disadvantages. Since the transmission from controller to variable element, Figure 11(B), is by heat transfer, the transmission characteristics are poor, resulting in considerable attenuation. Thermistors having separate heaters improve the transfer properties, but the difficulty in matching results in lower accuracy. During rapidly changing input conditions, the forced current of the feedback amplifier can build up excessive temperature. If the driver amplifier becomes saturated, the speed of response will fall sharply toward the relatively slow response time of the basic element. Accuracies to date have been better than one per cent. This may be extended by closer matching of variable elements.

Other basic elements can be substituted for the thermal element. For example, certain materials such as bismuth exhibit the Gauss effect; that is, they vary their electrical conductivity when placed in a magnetic field. The response to field strength changes is fast. A multiplier based on the Gauss effect of bismuth can be derived from a circuit exactly analogous to Figure 11(B).

One limitation on the use of bismuth is that dc actuation of the controller is required. But its speed of response and its accuracy and transmission factor compare favorably with thermal units.

Since bismuth has become available as insulated wire, more interest has been shown in these devices. A magnetic circuit that permits the close control of magnetic flux is shown in Figure 13. The dc bias is supplied by a permanent magnet slug. The dc control signal increases the resistance of one bismuth element while decreasing the resistance of the other, exactly analogous to the thermal multiplier circuit of Figure 11(B). Many isolated bismuth circuits can be installed on the same magnetic core.

A similar multiplying device uses a variable-gain amplifier. The gain is controlled in accordance with the variation of a high frequency reference input signal by means of a feedback loop. An input signal is applied as modulation to a carrier, and is then transmitted through the variable gain amplifier. Thus, output is proportional to the product of the signal and the gain-adjusting reference wave. The two outputs are separated by tuned circuits. This type multiplier follows the block diagram of Figure 11(A).

Similar type II multipliers can be developed using saturable reactors, but these do not ordinarily give closer than 95 per cent accuracy.

Table IV summarizes the characteristics of type II direct multipliers.

Table IV
CHARACTERISTICS OF TYPE II DIRECT MULTIPLIERS

a. **Isolation of all variables.**
b. **Reduction of response time by the factor of the gain around the amplifier feedback loop.**
c. **Linear relationship not required between the input and the adjustments of the control elements.**
d. **Multiplier accuracy closely related to the accuracy with which components are matched.**
e. **The nature of the control elements can cause variable gain around the feedback loop. This may introduce stability problems.**

INDIRECT MULTIPLIERS

Indirect multiplication depends on the indirect mathematical techniques listed in Table I. These are illustrated in block form in Figures 15 through 19. A variety of electronic, mechanical, and semiconductor types have been built to instrument these indirect techniques.

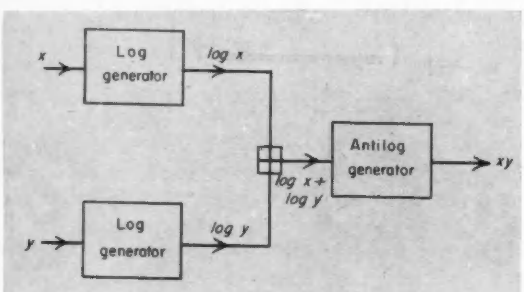
Figure 15 shows a logarithmic multiplier, available in several forms from commercial sources. Carefully designed units are capable of fractional per cent accuracies. The chief limitation is that input variables near and including zero and negative values cannot be used because of the nature of the logarithmic function. By adding a positive constant to each input, and subsequently separating it after multiplication, Figure 17, it is possible to extend the range.

Figures 15 and 16 show two alternate schemes for developing the antilogarithm. While the feedback circuit of Figure 16 is more complex, it has the advantage of using a single type of computing element. Some compensation for changes in operating conditions can be obtained if the three logarithm-generating elements are matched.

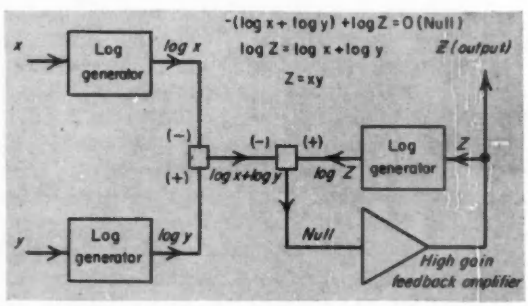
The squaring multiplier, Figure 18, has wide practical application. It can handle positive, negative, and zero values of the input. Since squaring is simpler than multiplication, involving only one independent variable, high accuracies can be obtained. Variable mu vacuum tubes, with square-law grid characteristics, can be used for low-cost low-accuracy multiplication.

The multiplier shown in Figure 19 is based on integrators. Since integrators are available with accuracies of one part in ten or twenty thousand, precise multiplication can be performed. This is the common approach in general purpose analog computers where most of the computations are performed by combinations of integrator circuits. It has the advantage of restricting the required variety of standard computing elements.

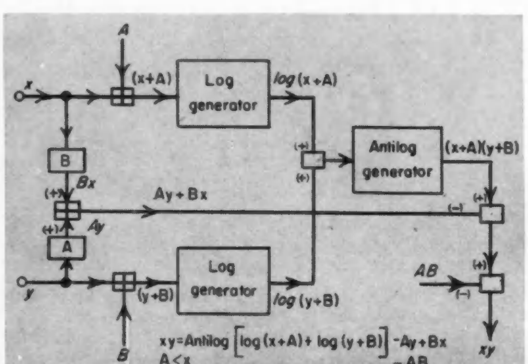
Figures 20 through 24 show specific multipliers that use these indirect techniques.



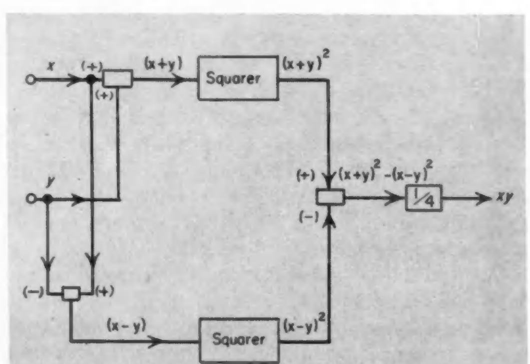
Block diagram of logarithmic multiplier. This arrangement requires an antilogarithmic generator. Fig. 15



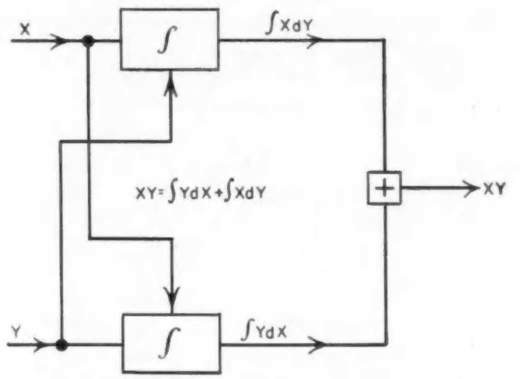
Logarithmic multiplier that uses feedback arrangement instead of a special antilogarithmic generator. Fig. 16



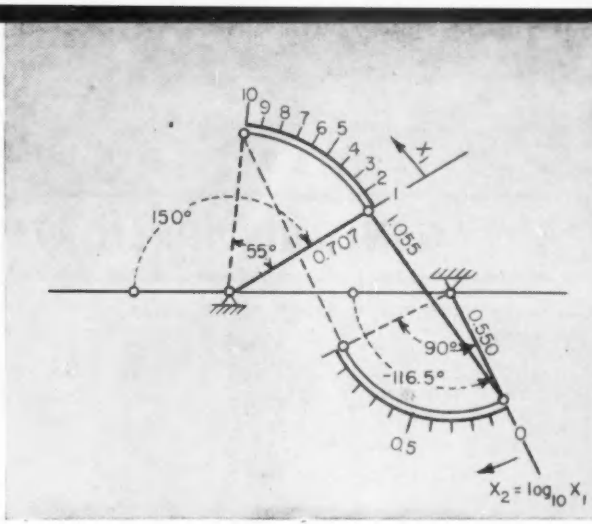
Modified version of the logarithmic multiplier shown in Figure 15. Positive constants *A* and *B* added to the inputs permit zero and negative values of the input. Fig. 17



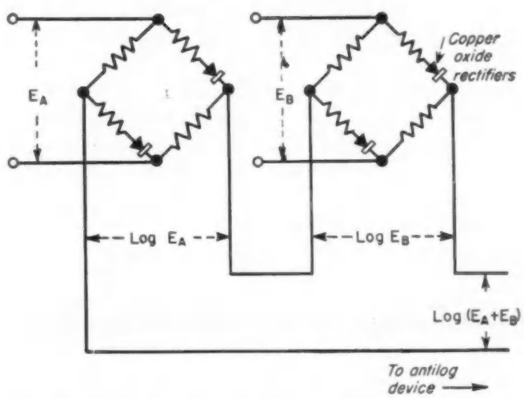
Block diagram of a square-law multiplier. Since it is simpler to generate an accurate square than it is to perform a straight multiplication, this arrangement yields high accuracies. Fig. 18



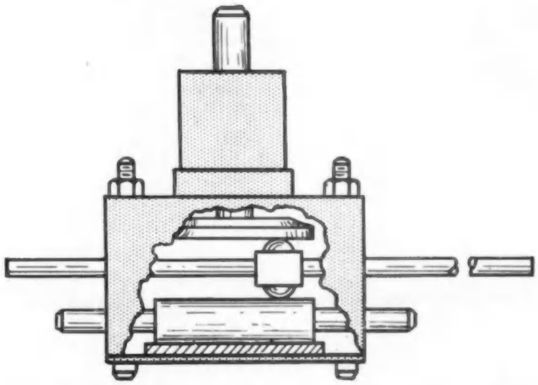
Multiplier based on summing two integrals. This approach is used in general purpose analog computers where precise integrators are available. Fig. 19



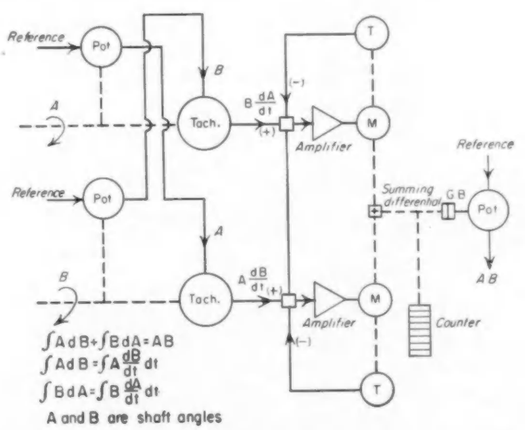
Linkage mechanism that will develop a logarithmic function accurately to within one per cent. More complex versions can be accurate to within 0.1 per cent. This device can be used in circuits shown in Figures 15, 16, and 17. Fig. 20



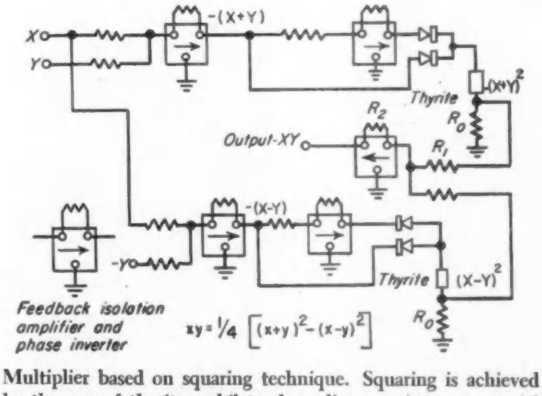
Semi-conductor elements can be used to generate logarithmic functions. This schematic shows the application of copper oxide rectifiers to the multiplication of two variables. The inputs cannot reverse sign or approach zero. Fig. 21



A more practical approach than that shown in Figure 22 is to use a mechanical integrator. This unit can directly integrate one shaft rotation with respect to the other. Multiplier accuracies can reach 99.99 per cent. Fig. 23

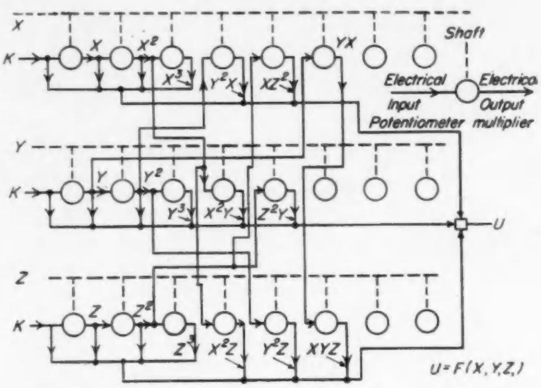


Straightforward application of the integral summation technique for multiplication, using electromechanical rotating components. This approach is uneconomical unless many of the components are already available in the computer, since integrators of the motor-tachometer variety integrate inherently only with respect to time. Fig. 22

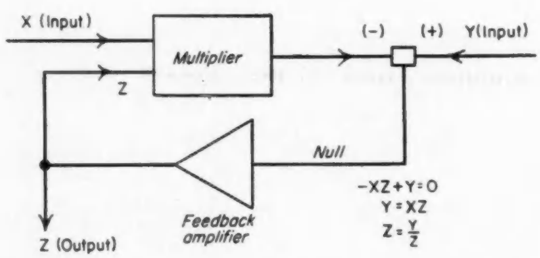


Multiplier based on squaring technique. Squaring is achieved by the use of thyrite, a bilateral nonlinear resistance material that can be trimmed by combination with fixed resistors to get a squaring action. The rectifier elements in the circuit serve as switches to maintain the necessary positive sign for the squared function regardless of the magnitudes and polarities of the inputs. Unit is suitable for operation over the low audio range at errors of about one per cent. Fig. 24

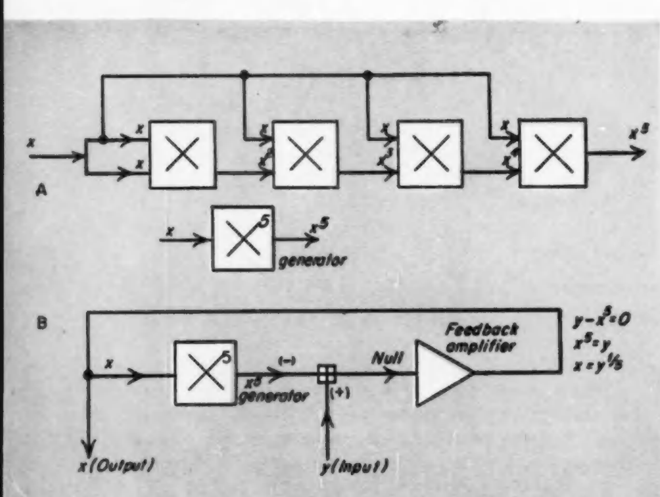
GENERAL APPLICATIONS OF MULTIPLIERS



Simplified schematic showing use of multipliers to develop a function of three independent variables. Theoretically, this approach can be extended to include any number of variables and to reach an accuracy corresponding to that of the basic multiplier. Isolation devices and attenuators are omitted for clarity. Fig 25



Dividing with a multiplier. General technique based on use of feedback. Fig. 26



Multipliers in cascade for generating integral powers of a variable. Schematic illustrates process of raising to a fifth power. Fig. 27(A)
(B)—Extracting the fifth root by use of feedback and a fifth-power generator.

Multipliers are widely used in industrial instruments, are key components in all computing devices, and are useful also for handling many other mathematical functions. For example, assume that a function, u, of three variables, x, y, and z, is to be generated electrically. This function can be expanded by a Taylor series as follows:

$$u = F(x,y,z)$$

$$u = F_x(x) + F_y(y) + F_z(z) + K_1x^2y + K_2xy^2 + K_3x^2z + K_4xz^2 + K_5y^2z + K_6yz^2 + K_7xyz.$$

$$F_x(x) = K_{x0} + K_{x1}x + K_{x2}x^2 + K_{x3}x^3 + \cdots$$

$$F_y(y) = K_{y0} + K_{y1}y + K_{y2}y^2 + K_{y3}y^3 + \cdots$$

$$F_z(z) = K_{z0} + K_{z1}z + K_{z2}z^2 + K_{z3}z^3 + \cdots$$

Thus a function of three variables, $F(x, y, z)$, can be expressed by a series of multiplications. Figure 25 shows a simplified schematic of a function generator using potentiometer multipliers. Seventeen potentiometers are required to achieve third-order accuracy. This technique can be extended to higher order terms and to more variables, but the number of potentiometers rapidly becomes prohibitive. The accuracy is directly limited by the accuracy of the multipliers. Other kinds of multipliers can be used in variations of this scheme.

Multipliers are used also to generate powers and roots and for division. Many applications require feedback techniques, Figures 26 and 27. Indirect multipliers using logarithms can solve problems of involution and evolution. Equipment economy can be effected where high or nonintegral powers and roots are involved.

SELECTED REFERENCES

a. WAVEFORMS, B. Chance, F. C. Williams, V. Hughes, D. Sayre and E. F. MacNichol, Jr., McGraw-Hill Book Co., 1949.

b. COMPUTING MECHANISMS AND LINKAGES, A. Svoboda, McGraw-Hill Book Co., 1948.

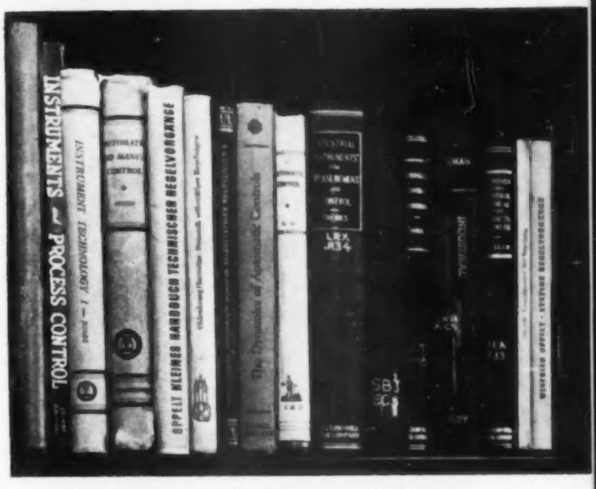
c. PATENT NO. 2,471,262, by Cousins of Bell Laboratories.

d. ANALOG COMPUTER FOR FLIGHT SIMULATION, A. C. Hall, AIEE Transactions, 1950.

e. AN ANALOG MULTIPLIER USING THYRITE, L. D. Kovack and W. Comley, Professional Group on Electronic Computers, I.R.E., June 1954.

BASIC BOOKS FOR YOUR

Control Engineering Library



1—INDUSTRIAL PROCESS CONTROL

Here are the books on the theory and practice of process control for: (1) the instrument engineer, (2) the process engineer, and (3) the student of theory

Thomas J. Higgins, University of Wisconsin

THE BOOK OF greatest consequence to date in the area of industrial process control is the splendid, recently (1954) published work by Oppelt, "Kleines Handbuck Technischer Regelvorgänge."[1] The author, one of the foremost European process control engineers, shows by his numerous patents and his scores of published papers a rare combination of competence and originality in both application and theory. He has gained his application experience during a long stint as the leading design engineer of Hartmann and Braun, a major German instrumentation and control firm. The book is of inestimable value to the process control engineer.

Rooted in the author's earlier texts, "Grundgesetze des Regelung" (1947) and "Stetige Regelvorgänge" (1949)[2,3], the new book integrates, expands, and extends them. Its 447 pages concisely delineate:

- the technical and structural "philosophy" of process control;
- fundamental and intermediate theory;
- the makeup and operating characteristics of the instruments and components used in control systems;
- the considerations necessary in joining philosophy, theory and equipment in the actual design of automatic control systems for plants.

The ten chapters of context are buttressed by 353 multi-fold, excellently prepared figures, 110 short tables, 3 major tabulations, and detailed numerical solutions of many illustrative process control problems. Both the beginner and the experienced process control engineer should find the book a most useful working aid. It offers the beginner a well-rounded, carefully detailed precis of process control theory and application as it stands today. It provides the advanced control engineer with specialized material.

The author uses the frequency response approach. Consequently the mathematical knowledge required to grasp the contents consists of elementary calculus and elementary complex algebra. A feature of the text, stemming from the frequency response approach, is the illumination of the theory by abundant locus diagrams and frequency response plots. They are introduced where pertinent to the development of a topic, collected in tables for use in design, and gathered in a 35-page "atlas" wherein the locus diagrams and corresponding time-domain inversions of the most commonly encountered transfer functions are coupled in adjacent columns.

The systematic notation and symbolism is in accord with German standards DIN 19226. This and a development of the theory in parallel with the more highly-developed servomechanism theory con-

CITATION: *"To Thomas James Higgins for his tireless efforts in the interests of better teaching; for his capacity to stimulate others in the classroom, in committee meetings, and in meetings of professional groups; for his many published papers, critical reviews, and offerings in technical conferences; for his effective contributions to undergraduate education, to graduate education, to research; for his genuine thoughtfulness of others; and for his unswerving devotion to the teaching profession, we award this ninth George Westinghouse Award." June 17, 1954.*

tribute to a marked clarity and make for easy reading by the control engineer who is not involved in process control.

If a comparable handbook in English is not forthcoming in the near future our publishing houses and technical societies should consider making a translation of the book available to English-speaking control engineers.

TEXTBOOKS

Although well-integrated, Oppelt's volume is yet a handbook pertinent to process control in toto. It is not a textbook devoted to the logical development of process control theory and its application. "Dynamik Selbsttatiger Regelungen" by R. C. Oldenbourg and H. Sartorius is among the best of such books. The first edition[4] (1944) of this book is well known in the United States through the translation[5] (1945) by H. L. Mason and published by ASME. It is only slightly changed in the second edition[6] (1951). The total second edition will comprise two volumes. To date, only the first has appeared. It is essentially the first edition, strengthened by the correction of errors. For the linguistically limited engineer, [Ed.—that's most of us] the ASME text is an excellent introduction to process control theory through the Laplace transform.

The second volume of Oldenbourg and Sartorius will, perhaps, advance process control theory considerably through the use of the procedure and transform theory worked out during the past decade for analysis of relay, sampled-data, carrier-frequency, nonlinear element, and kindred servo systems. There is no indication whether anyone will write a similar volume in English, nor whether the second Oldenbourg and Sartorius volume will be translated.

A less inclusive, less highly theoretical book, but one which well illustrates the current status of process control analysis among English-speaking engineers, is the (1951) text, "Fundamentals of Automatic Control"[7] by G. Farrington, consultant with the English instrumentation firm, Ilford, Ltd. The book is couched in "process control language" and uses the simpler Heaviside operational calculus rather than the more rigorously-based and technically-fruitful but more-difficult-mathematically Laplace transform. It is the only modern text directed toward industrial process control engineering, written originally in English. It is an excellent introduction to the subject for both the practicing engineer who desires a broad perspective and the earnest student of theory desiring an introductory briefing prior to a thorough study of the German works.

Of the remaining texts, those best known to the American and English engineer are D. P. Eckman's, "Industrial Process Control"[8] (1945), and E. S. Smith's, "Automatic Control Engineering"[9] (1944). "Industrial Process Control" is more descriptive than analytical in nature and the treatment is now rather dated. A second, revised edition will appear shortly. "Automatic Control Engineering" is considerably more theoretical in nature. However, (and this is indicative of the strides made in the application of process control theory during the past decade), the mathematical content and techniques which would be the core and basic tools of a currently-written text, such as those by Farrington and Oppelt, are in the appendices of Smith's book. Nonetheless, this text—because of its numerous tables, discussions of physical principles and properties, and other enduring content—can be read with profit.

INSTRUMENTATION TEXTS

Today, instrumentation plays a major role in the actual accomplishment of automatic process control. Therefore, a chronological listing of the better-known texts in English is of interest, especially be-

cause these, perforce, discuss process control theory to some extent. The process control engineer will find the following worth his attention:

Rhodes[12] (1941)
Feller[13] (1947)
Eckman[14] (1950)
Jones[15] (1953) (this one especially)
Behar[16] (1951) (a handbook)
the monograph "Instruments and Process Control"[17] (1947)

These texts are concerned with instrumentation in a broad sense. They list books on special phases of instrumentation (see, for instance, the excellent bibliography in Jones' book).

The concisely-written sections on process control and instrumentation in certain standard chemical and mechanical engineering handbooks[17-20] are worth some attention.

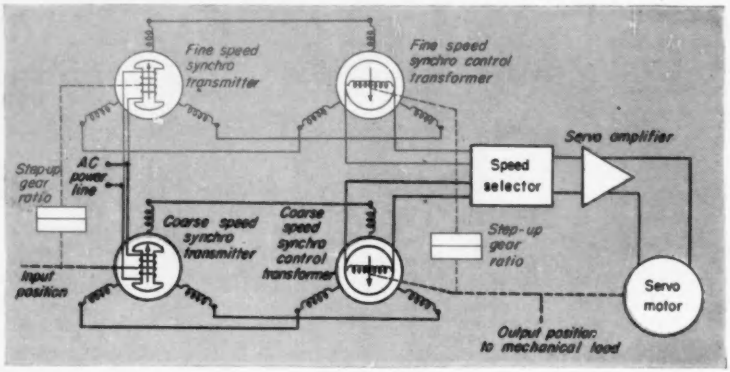
The texts, handbooks, and journals mentioned are encompassed here under industrial process control (an area closely allied with chemical engineering). Even so they contain much of interest to the electrical or mechanical engineer who is particularly concerned with servomechanisms and computers.

REFERENCES

1. *KLEINES HANDBUCH TECHNISCHER REGELVORGANGE,* W. Oppelt, 447 pp. Verlag Chemie, GMBH, Weinheim/Bergstr., 1954.
2. *GRUNDGESETZE DER REGELUNG,* W. Oppelt, 118 pp. Wolfenbutteler Verlagsanstalt GMBH. Wolfenbuttel-Hannover, 1947.
3. *STETIGE REGELVORGANGE,* W. Oppelt, 144 pp. Wissenschaftliche Verlagsanstalt K. G. Hannover in Gemeinschaft mit Wolfenbutteler Verlagsanstalt GMBH. Wolfenbuttel, 1949.
4. *DYNAMIK SELBSTTATIGER REGELUNGEN,* R. C. Oldenbourg and H. Sartorius, 283 pp. R. Oldenbourg, Munchen und Berlin, 1944.
5. *THE DYNAMICS OF AUTOMATIC CONTROLS,* R. C. Oldenbourg and H. Sartorius, (translated and edited by H. L. Mason), 276 pp. The American Society of Mechanical Engineers, New York, 1948.
6. *DYNAMIK SELBSTTATIGER REGELUNGEN,* R. C. Oldenbourg and H. Sartorius, Band I: *ALLGEMEINE UND MATHEMATISCHE GRUNDLAGEN STETIGE UND UNSTETIGE REGELUNGEN NICHTLINEARITATEN,* Edition 2, 258 pp. R. Oldenbourg, Munchen, 1951.
7. *FUNDAMENTALS OF AUTOMATIC CONTROL,* G. H. Farrington, 285 pp. Chapman and Hall, Ltd., London, 1951.
8. *PRINCIPLES OF INDUSTRIAL PROCESS CONTROL,* D. P. Eckman, 237 pp. John Wiley and Sons, Inc., New York; Chapman and Hall, Ltd., London, 1945.
9. *AUTOMATIC CONTROL ENGINEERING,* E. S. Smith, 367 pp. McGraw-Hill Book Company, Inc., New York and London, 1944.
10. *UNMITTELBARE REGELUNG,* W. Schmidt, 112 pp. VDI-Verlag, Berlin, 1939.
11. *MITTELBARE REGLER UND REGELANDLAGEN,* F. Engel, 240 pp. VDI-Verlag, Berlin, 1944.
12. *INDUSTRIAL INSTRUMENTS FOR MEASUREMENT AND CONTROL,* T. J. Rhodes, 573 pp. McGraw-Hill Book Company, Inc., New York and London, 1941.
13. *INSTRUMENT AND CONTROL MANUAL FOR OPERATING ENGINEERS,* E. W. F. Feller, 426 pp. McGraw-Hill Book Company, Inc., New York and London, 1947.
14. *INDUSTRIAL INSTRUMENTATION,* D. P. Eckman, 396 pp. John Wiley and Sons, Inc., New York; Chapman and Hall, Ltd., London, 1950.
15. *INSTRUMENT TECHNOLOGY,* E. B. Jones, Volume I: *MEASUREMENT OF PRESSURE, LEVEL, FLOW AND TEMPERATURE,* 315 pp. Butterworths Scientific Publication, London, 1953.
16. *THE HANDBOOK OF MEASUREMENT AND CONTROL,* Edited by M. F. Behar, 291 pp. The Instruments Publishing Company, Inc., Pittsburgh 12, Pa., 1951.
17. *INSTRUMENTS AND PROCESS CONTROL,* 233 pp. Delmar Publishers, Inc., Albany, N. Y., 1947.
18. *PROCESS CONTROL,* R. W. Porter and D. M. Considine, Section 19, Chemical Engineers Handbook, McGraw-Hill Book Company, Inc., New York, 1950.
19. *AUTOMATIC CONTROL,* E. D. Haigler, pp. 2092-2107, Marks Mechnical Engineers Handbook, McGraw-Hill Book Company, Inc., New York, edition 5.
20. *CONTROL MECHANISMS. AUTOMATIC REGULATORS,* E. S. Smith, Section 17, pp. 17.02-17.15. Kent's Mechanical Engineers Handbook, Vol. 2, "Design and Production," John Wiley and Sons, Inc., New York, edition 12, 1950.
21. *INSTRUMENTATION,* D. P. Eckman, Section 18, pp. 18.01-18.38. Kent's Mechanical Engineers Handbook, vol. 1, "Power," John Wiley and Sons, Inc., New York, ed. 12, 1950.

In addition to well-known American journals, several British and German journals devote considerable editorial space to articles on process control theory and application. These journals, not too well-known among process engineers in the United States, certainly ought to be available in the technical libraries of all colleges, offices, and plants where process control engineering is practiced.

WHY SWITCHING CIRCUITS ARE NECESSARY



The portion of the schematic in black shows a conventional synchro transmitter-synchro control transformer positional transmission system. A change in transmitter shaft angle excites the system and causes stator currents to flow through the control transformer. A magnetic field is set up in the control unit, parallel to the transmitter field but 180 deg out of phase. The output is driven to a null by the amplifier-servomotor feedback loop. The static accuracy of this system is limited by the accuracy of the synchros. The voltage output of the control transformer may not be zero when the output and input shaft positions are in correspondence.

To reduce the static error of the system, the portion of the schematic shown in green can be added. Two synchro transmitters are geared together on the input shaft and two control transformers are geared together on the controlled shaft. This is known as a multi-speed synchro system. If the output of the original (coarse speed) control transformer is fed to the amplifier when the positional error is large, and the output of the added (fine speed) control transformer when the error is small, then the system static error will be $1/n$ times the orignal error, where n is the step-up gear ratio.

The speed selector must choose the correct input to the amplifier depending on the magnitude of the error. This article covers the design of one major type of speed-selector circuit.

Note: Part of this article is based on work originally done at the M.I.T. Servomechanisms Laboratory.

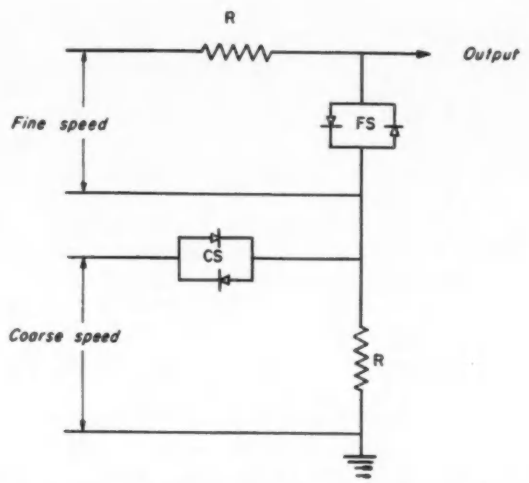
HOW TO DESIGN

Speed Switching Circuits

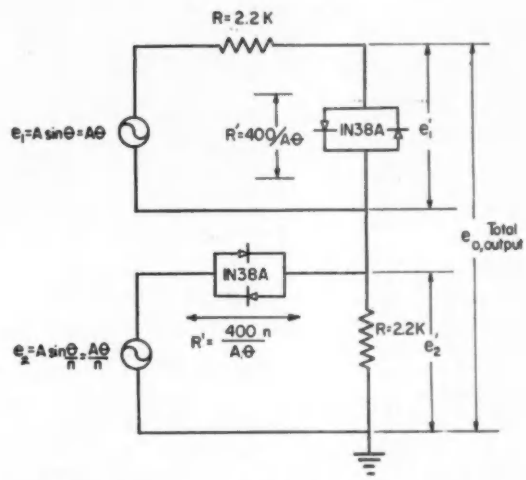
USING NONLINEAR ELEMENTS

First of two articles covering the design of switching circuits for two-speed positional servomechanisms. This one tells about continuous circuits using nonlinear resistance elements. Next month's deals with the design of discontinuous circuits using neon lamps.

BASIL T. BARBER, Sperry Gyroscope Co.



Basic speed-switching circuit of the continuous type. At low error levels, bridges FS and CS have a high resistance so that fine speed signal predominates. At high error levels, bridge resistances are low, and coarse speed signal predominates. Fig. 1



Equivalent circuit to that shown in Figure 1 showing specific values for circuit elements. Fig. 3

A two-speed data-transmission system is often used in positional servomechanisms to increase the system's overall accuracy, prevent positional ambiguity, and expand its angular resolution. These advantages are attained, however, only at the cost of additional components and the introduction of some means of synchronizing the two-speed error detector. The problem of switching from coarse to fine speed is basically one in which the switching point is determined by the relative amplitude difference of the coarse and fine synchro outputs. The switching operation can be accomplished with relays, biased vacuum diodes, rotary mechanical switches, and nonlinear elements.

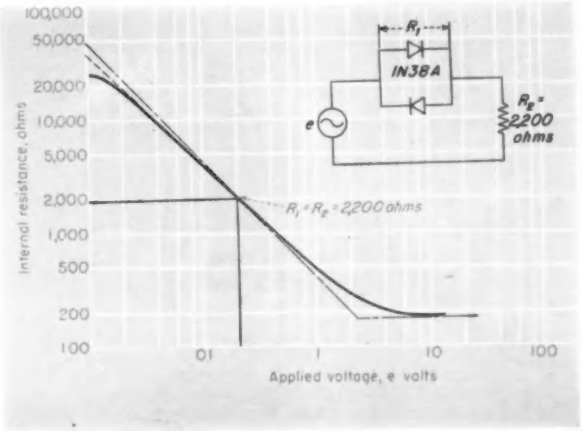
The last approach has several inherent advantages: rapid switching action, high accuracy and sensitivity, small switching transients, and overall simplicity. Two switching methods can be used:

CONTINUOUS—Its selective properties are based on the fact that the internal resistance of some elements is a nonlinear function of applied voltage. A network of linear resistors and these elements is connected across the output of the fine and coarse synchros so that the effective total output is predominantly caused by the fine synchro at small errors and by the coarse synchro at large errors.

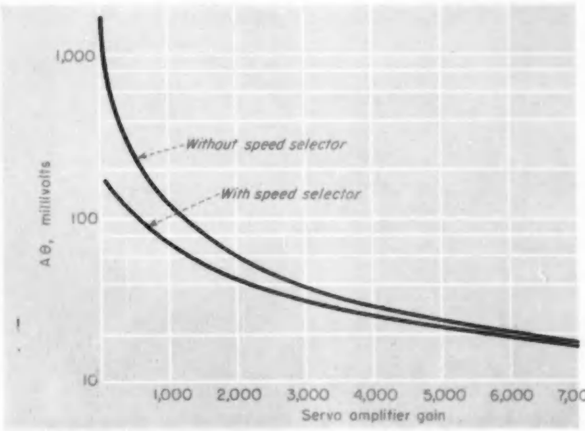
DISCONTINUOUS—The switching point from coarse to fine speed is made to coincide with the firing point of a neon lamp. The high impedance ratio between the nonconducting and conducting states of the neon lamp is used in a voltage-divider fashion to bypass one synchro output to ground, while the other is channeled to the servo amplifier.

CONTINUOUS METHOD

Figure 1 shows a speed switching circuit of the continuous type using crystal diodes. The crystals in each pair of dividers are connected back-to-back



Average internal resistance of a 1N38A crystal as a function of applied voltage. Voltage varied from 10 mv to 20 v. Fig. 2



Dynamic range of servo system, with and without speed selector, as a function of servo amplifier gain. Fig. 4

NOMENCLATURE

e_1 = fine synchro output before switch
e_1' = fine synchro output after switch
e_2 = coarse synchro output before switch
e_2' = coarse synchro output after switch
A = maximum synchro output
θ = angular displacement
R' = internal resistance of crystals
n = gear ratio between fine and coarse speed
e_0 = total output of switch
K_v = velocity constant

and present a conducting path for both directions of the applied alternating voltage. At low error levels the crystals have a high resistance level and with the series resistors form a high bleeder for the fine output and a low bleeder for the coarse speed output. The switch output will be essentially the fine synchro output.

At high error levels the crystals have a low resistance value and the process reverses, giving an output dominated by the coarse output. The degree of amplitude discrimination inherent in this circuit depends on the variation of crystal internal resistance with applied voltage.

The average internal resistance of a pair of crystals is shown in Figure 2. The load resistor R_2 is chosen equal to 0.1 of the internal resistance of the crystals at minimum synchro output. This assures an effective amplitude attenuation of at least 20 db between the fine and coarse synchro outputs near the zero region of the system.

Most synchros null at about 20 millivolts. From the figure, the crystals have an internal impedance of about 20,000 ohms at this level. Therefore R_2 is made 2,200 ohms. When the applied voltage is less than 1v the internal resistance of the crystals is approximately 400/e. The parameters chosen are for a speed selector feeding a high impedance servo amplifier. For a low-input impedance amplifier or higher synchro outputs, heavier crystals or selenium rectifiers with higher current rating should be used. Usually excessive loading will have adverse effects on the amplitude discrimination of the selector in addition to causing a serious transmission loss.

Assuming that for small angles sin θ equals θ, the output e_o of the equivalent circuit shown in Figure 3 can be approximated by

$$e_o = e_1' + e_2'$$

$$e_o = \left(\frac{A\theta}{R + 400/A\theta}\right)\left(\frac{400}{A\theta}\right) + \left(\frac{A\theta/n}{(400n/A\theta) + R}\right)R \tag{1}$$

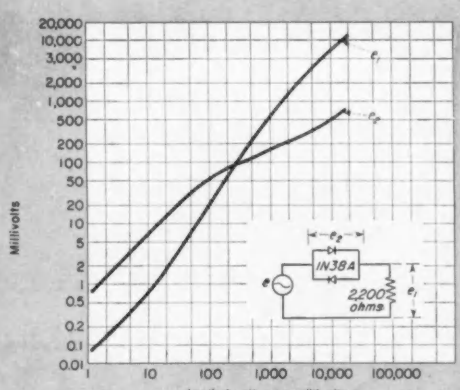
$$e_o = \frac{400A\theta}{RA\theta + 400} + \frac{R(A\theta)^2}{n(400n + RA\theta)}$$

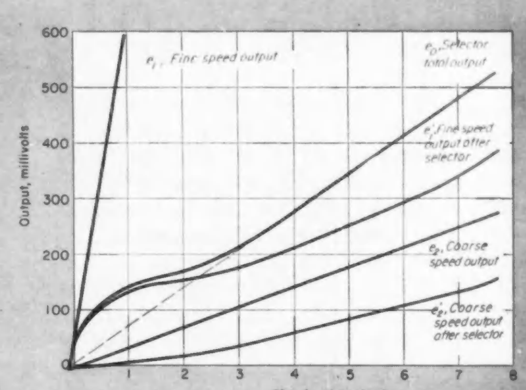
Since R is about 2,000 ohms, and n varies from 10 to 50, the second term of Equation 1 is small. Therefore

$$e_o = \frac{400A\theta}{RA\theta + 400} = \left(\frac{400}{Re_1 + 400}\right)e_1 \tag{2}$$

This indicates that the output of the speed selector causes a nonlinear loss over the principal operating region of the servo. However, near the zero region, where the servo will be operating most of the time, Equation 2 closely approximates the fine synchro output and the nonlinear loss should cause no adverse effect.

Figure 4 shows the dynamic range of a servo system, with and without the speed switching circuit,





Voltage distribution of e_1 and e_2 as a function of the applied voltage. Fig. 5
Plot of total output e_o and the output of the fine and coarse synchros e_1 and e_2; before and after the switch as a function of fine input angle. Fig. 6.

as a function of servo amplifier gain. Symmetrical saturation after a maximum output of 115v is assumed. For gains higher than 3,000 the reduction in the system's dynamic range is negligible. At low gains the dynamic range is reduced by a ratio proportional to

$$\frac{400}{RA\theta + 400}$$

and an additional gain, proportional to the inverse of the compression ratio, may have to be cascaded with the original amplifier in critical applications.

Graphical Analysis

Since Equation 2 is not valid for inputs higher than 1v, a graphical method is used to investigate the response of the selector to a complete cycle of the course synchro output. With e_1 equal to $20\sqrt{2}\sin\theta$, e_2 equal to $20\sqrt{2}\sin\theta/n$ and using the graph of Figure 2, the outputs of e_1' and e_2' of Figure 3 can be plotted as the input varies from 10 mv to $20\sqrt{2}$. This is done in Figure 5. Figure 6 shows the total output e_o plotted against the fine input angle θ and the outputs of the fine and coarse synchros before and after the switch.

Since the output e_o is the vector sum of e_1' and e_2', it is possible for e_o to become zero for some value of θ other than the original zero. This would result in a false null. From the curves of Figure 6 the only point where e_1' and e_2 are both maximum and of opposite polarity is when θ equals 230 deg, giving an output

$$e_o = e_1' + e_2' = 6.2 - 2.2 = 4\text{v}$$

After this point the output will keep continually increasing to the maximum value of the coarse synchro output, even though the fine synchro output becomes zero and reverses polarity several times.

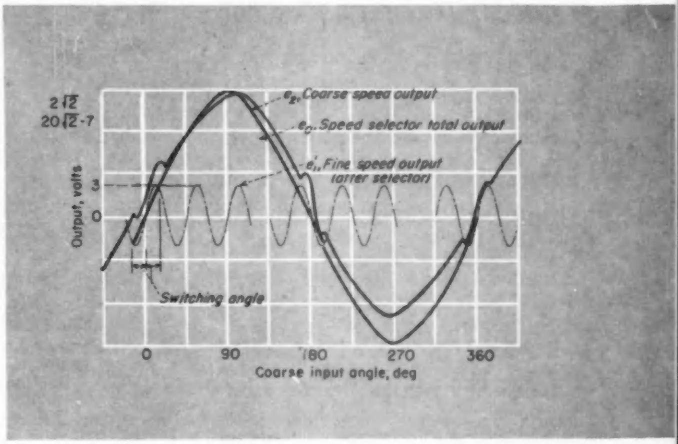
Figure 7 shows the amplitude response of the speed switch for a complete cycle of the coarse synchro. Its output is zero also at θ equals 180 deg (course) and the system performance is similar to that of the zero degree point. However, the 180 deg region is either a stable or unstable null depending on the value of n. If the rate of change of e_o is negative in this region, the 180 deg point is an unstable null. This applies when n is an odd number, and there will be no ambiguity. If n is an even number, the rate of change of e_o is positive in the 180 deg region. This results in two unstable nulls, symmetrically located about the 180 deg point and at a distance equal to the switching angle. The 180 deg point is now a stable null resulting in a positional ambiguity. In practice, if n is an even number and cannot be physically modified, a "stick-off" voltage is inserted in cascade with the coarse synchro output, inverting the slope of the output in the 180 deg region and transforming the 180 deg point into an unstable null. This requires mechanical realignment of the coarse synchro.

Dead Space

In designing a speed selector similar to the one described, the effective range of the fine synchro must be made greater than the dead space of the coarse synchro. The dead space must include any gear backlash, motor dead space referred back to the fine synchro, friction, and other nonlinearities that are present.

Temperature Range

Temperatures ranging from 0 to 75 deg C do not effect the selector. As the temperature decreases, the fine synchro output increases while the coarse synchro output decreases—a condition that may result in false nulls at very low temperatures. On the other hand, high temperatures tend to accentuate the effects of the nonlinearities in the system.



Amplitude response of the speed selector for a complete cycle of the coarse synchro. Fig. 7

The output is substantially free from harmonic distortion down to 20 mv. The crystal time lag is a few microseconds. Therefore, no phase shift occurs when the selector is used with carrier frequencies up to 10 kc.

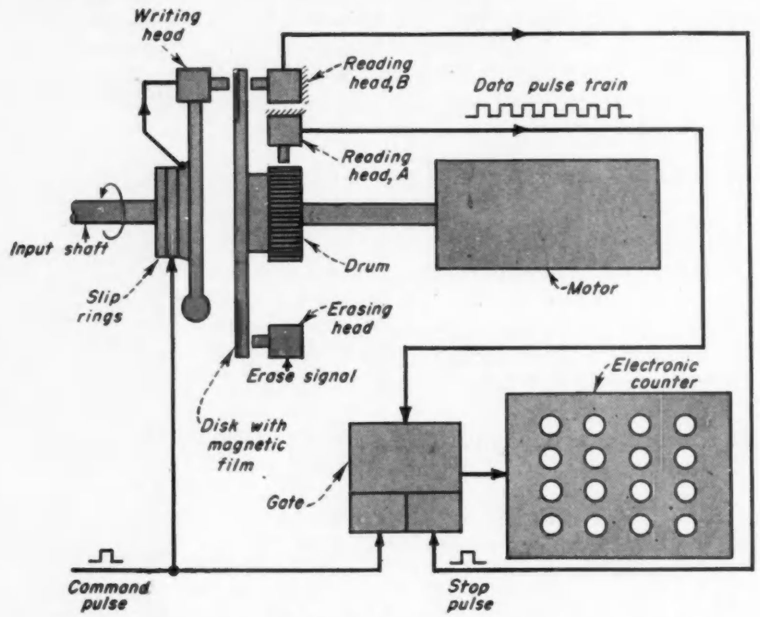
SELECTED REFERENCES

1. *PRINCIPLES OF RADAR*, J. F. Reintjes and G. T. Coate, M.I.T. Radar School, McGraw-Hill Book Co., 1952. Chapter XII, pp 12-28.
2. *INSTRUMENT SERVOMECHANISMS*, A. C. Hall and W. Deerhake, Technology Press. Pp 22-26, 91, 94-96, 147.
3. *THEORY OF SERVOMECHANISMS*, H. M. James, N. B. Nichols and R. S. Phillips, M.I.T. Radiation Lab. Series, McGraw-Hill Book Co., 1947. Pp 83-88.
4. *AUTOMATIC FEEDBACK CONTROL*, W. Ahrent and T. Taplin, McGraw-Hill Book Co., 1951. Pp 246-248.
5. *COMPONENTS HANDBOOK*, J. F. Blackburn, M.I.T. Radiation Lab. Series, McGraw-Hill Book Co., 1948. P 327.
6. *ELECTRONIC INSTRUMENTS*, I. A. Greenwood, Jr., J. V. Holdam, Jr., D. MacRae, Jr., M.I.T. Radiation Lab. Series, McGraw-Hill Book Co., 1948. Pp 27, 372-75.
7. *RELAY SWITCHING CIRCUITS FOR SYNCHRONIZING A TWO-SPEED SYNCHRO DATA SYSTEM*, T. Mahoney, M.I.T. Servomechanism Lab., Eng. Report No. 12, DIC Project 6546.

Digitalize Shaft-Position by Induction

A. H. KUHNEL, The Austin Co.

Tiny analog-to-digital converter with no commutator divides a revolution into 4,000 or more parts. Having no fixed output code, it can speak the language of any digital computer. This flexibility fits it for all data-reduction systems.



Basic quantizer circuit as developed at the Naval Research Laboratory. Fig. 1

Many devices have been developed recently that will produce a digital output when actuated by a rotating shaft. Called analog-to-digital converters or shaft digitizers, most of them use a rotor consisting of one or more coded disks or commutator elements to produce the digital output. While some have worked well in specific applications, they have the limitations listed in the table.

In contrast, the shaft-position quantizer is a small unit that couples directly to the shaft and gives an instantaneous analog-to-digital sampling. The precise value of each increment, and the code or language in which the output is expressed can be selected in accordance with the requirements of the problem and is not fixed by the design of the quantizer.

MAGNETIC PRINCIPLE

This unit, shown in Figure 1, uses an entirely different concept, originally developed at the Naval Research Laboratory under the direction of D. H. Gridley. A drum carries a track of uniformly spaced divisions around its circumference. These are engraved in a magnetic material. A fixed reading head, A, picks up a continuous train of pulses as the drum is driven at a constant speed. A thin disk, coated with a magnetic film, is mounted on the face of the drum and rotates with it.

The writing head is mounted on

LIMITATIONS OF CODED-ROTOR DEVICES

PHYSICAL SIZE
Too large to be conveniently installed in many applications.

MULTIPLE LEADS
Usually require at least one lead for each significant digit. This may be awkward, especially where the leads must be brought in through slip rings.

INFLEXIBLE CODING
Output code is normally determined by the construction of the rotor assembly so that external equipment coding must be matched to the output code available.

SLOW AND INDETERMINATE SAMPLING
In some devices it is necessary to brake the rotor to a full stop before a data sample can be taken. Then the precise time of sampling is indeterminate. In other devices, solenoids keep the sensing elements out of contact with the rotor except during sampling or the output may be continuously available if the rotor is operated at slow speeds. These characteristics place limits on both sampling rate and accuracy.

GEARING ERRORS
Where successive rotors are coupled through sets of cascaded gears, accumulated backlash and shaft wind-up can cause errors.

COMPLEXITY
Complex construction can create problems in installation, operation and maintenance.

the input or data shaft, which is concentric with the motor shaft but not coupled to it. An external command pulse is supplied to the writing head and in turn is recorded on the face of the disk at a point corresponding to the instantaneous position of the writing head. This pulse is read out by the fixed reading head, B. The angle of travel of this recorded pulse, between the instant of writing and read out, is the instantaneous angular position of the data shaft at the time the pulse was written as measured from fixed head B.

To measure this angle, the train of pulses produced by reading head A is sent to an electronic counter through a gating circuit. The counter is cleared by external circuits prior to the initiation of the command pulse. This pulse is simultaneously delivered to the writing head and to the gate, thereby permitting the pulse train to pass into the counter at the instant of command. When the command pulse is subsequently read from the disk by head B, it blocks the gate so that no further pulses enter the counter. Then the number that is stored in the counter is the desired angular measurement in units, determined by the number of divisions around the circumference of the drum. The erasing head clears the disk after a data sampling.

The commercial unit, Figure 2, is based on this principle but is simpler and more compact. Only two magnetic heads are required since the command pulse is not recorded on a disk within the unit.

The unit consists of a small synchronous motor with a double-ended shaft. A precisely engraved disk is mounted at each end of the motor. A fixed magnetic head is mounted opposite the disk at the rear of the unit and is the reference for angular measurement. A revolving magnetic head is mounted opposite the disk at the front of the unit on an input shaft that extends out through the front of the case. Only five leads are required to operate the quantizer.

FLEXIBILITY IN RESOLUTION

Resolution—the number of discrete increments into which the circle of revolution is divided—is determined by the number of divisions on the disks. With a 2 in. outer diameter, the disks have a circumference of about 5 in. To obtain a resolution of 1 part in 4000 directly would require slots spaced .00125 in. on centers. The machining of slots to this spacing is impractical.

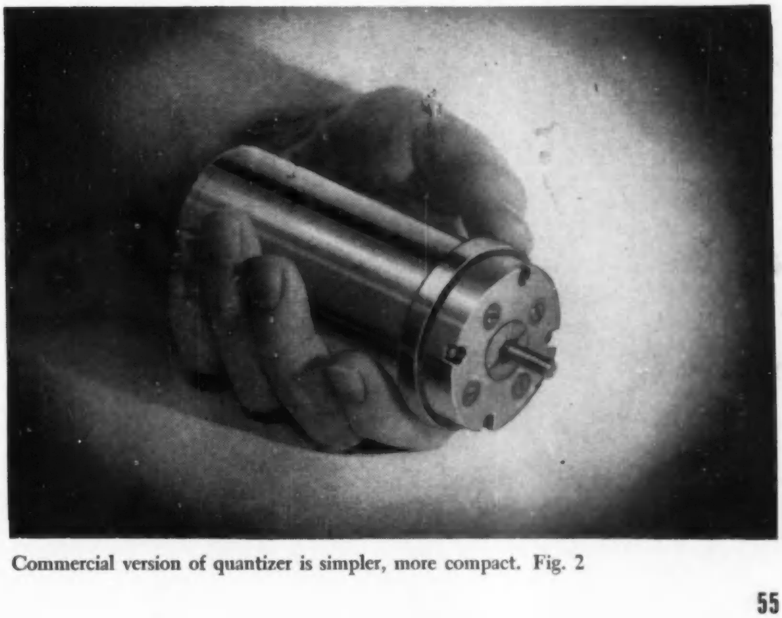
The same resolution is obtained by using 500 equally spaced slots on the disk and electronically multiplying the frequency of the output pulses by eight. This combination gives an overall resolution of 8 times 500 or 1:4,000 for the circle, with the slots at a center-to-center spacing of .01 in. This accuracy is obtained by precise engraving of the disks and by limiting phase shift in the output pulses to less than .0625 of a cycle of the raw pulses.

For satisfactory operation, the pulse counter must be cleared one cycle of the motor frequency (1/60 sec) prior to the arrival of the command pulse. The control unit contains the electronic multiplier circuits and the gates that control the admission of pulses into the counter. Since the pulse frequency, after multiplication by 8, is 240 kc, the time involved in taking a reading can be as much as 1/60 second (the time required to count to 4000 at this pulse frequency). However, the number obtained at the end of the count represents the position of the data shaft at the time of arrival of the command pulse, and not the position at the end of the count. Thus, the precise time of sampling can be controlled by the demands of the external equipment. In this particular unit, the time of sampling is controlled to within two microseconds, or less than one-half of the least significant digit.

SAMPLING RATE

It follows that a maximum of three cycles (3/60 sec) must be allowed for one data sampling and the maximum sampling rate is 20 samples per second. However, pulses are always continuously available from the magnetic heads of the quantizer. If these pulses are fed to two control units in parallel, and these units alternately take samples, 40 samples per second can be obtained. In fact, the number of samples per second is limited only by the number of control units it is economical to use. Accuracy is not reduced by operating a number of control units from one quantizer.

While the quantizer discussed above uses a 60-cycle two-pole motor with the disks divided into 500 parts and a multiplication factor of eight, any or all of these parameters can be varied. For example, if the disks are divided into 512 instead of 500 equal parts, and the other parameters are unchanged the quantizer divides the circle into 4096 parts. This is a convenient combination for a system operating in the binary code. Again, using a disk with 450 divisions and a multiplying factor of 8, or 360 divisions and a multiplying factor of 10, produces 3600 increments or 0.1 degrees per increment. A 400-cycle 4-pole motor permits a sampling rate



Commercial version of quantizer is simpler, more compact. Fig. 2

of up to 60 per second.

USE WITH DIGITAL COMPUTERS

The previous discussion has assumed that the output pulses are recorded in an electronic counter. This is convenient in many applications since the counter serves as a temporary memory to be read out when desired. When the quantizer is used as an input to a digital computer the electronic counter becomes redundant and can be omitted.

This unit can be automatically interrogated by a digital computer at any time and will furnish the precise status of an event at that instant. Any event that can be measured by the position of a shaft lends itself to this technique. This can be the setting of a valve in a chemical process, the position of the bed of a lathe, or the stroke of a piston in an actuator.

Acknowledgement: The author acknowledges the contributions of J. R. Poole, C. P. Cole and W. J. Melan-Kamski to the design of the Austin unit.

The Hottest Thing in Graphic Panels

G. JEWETT CRITES, F. J. Stokes Machine Co.

The vacuum system for a new 1,000-lb vacuum-melting furnace at the Utica Drop Forge and Tool Corp., Utica N. Y., is remotely controlled manually from a graphic panel. Graphic display is common in petroleum and chemical processing plants. But the Utica installation is its first known application to alloy production.

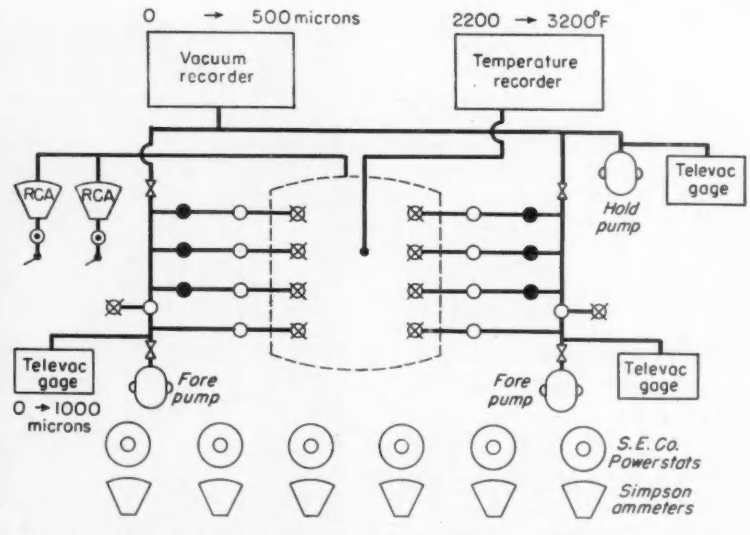
The furnace is the largest yet constructed in this country for melting and centrifugally casting high-temperature alloys under vacuum. Utica will use it and another of the same size to make high-purity alloys, of superior heat-resisting properties, for turbine blades in advanced jet engines. Temperature of the melt is approximately 2,900 F. Pressures in the vacuum chamber average less than 10 microns.

At a point most convenient for the operator to observe the melting and casting within the chamber through sight-glasses, the control panel is perched on top of the vacuum chamber. From this location he cannot see the valves and pumps of the vacuum system. Therefore, the control panel graphically displays the status of each pump and valve.

Indicators, recorders, and manual controls are all standard. The schematic drawing shows the relative position and function of each component.

Arranged in the center of the panel against a background whose outline suggests the shape of the vacuum chamber, and linked by red lines simulating the vacuum piping system, are eight two-position switches, which operate the valves at the vacuum chamber outlets to the pumps. They are flanked by an equal number of green indicating lamps. Red lamps indicate when each of the six booster pumps is operating. Further from the center, a pair of switches and accompanying lamps operate the valves that connect the forepumps to the high vacuum line.

The panel gives the operator all information he needs to regulate high-purity alloy production.



Blankets to Keep You Cold

A. J. MONROE, The J. B. Rea Co.

One of the earliest mentions of the anesthetic properties of cold dates back to the Napoleonic wars. A surgeon attached to the French Army then invading Russia noted that soldiers who had lain in the snow for some time suffered less pain during amputations and apparently suffered less post-operative shock than was normally experienced by warmer patients.

In more recent years, there has been a revival of interest in the use of induced subnormal body temperatures for safe anesthesia and for therapy in cases of shock. Several medical groups in the U. S. are investigating the technique of hypothermia, as this chilling process is called. Preliminary estimates of the value of the technique have, in general, been enthusiastic.

It has been used with particular success as an anesthesia in major cardiac surgery. At low temperatures it is possible to interrupt the flow of blood through the heart for more than fifteen minutes without causing damage to the brain.

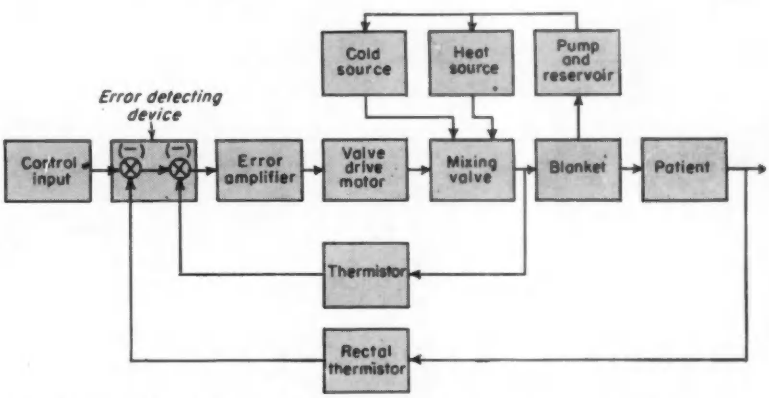
Body temperature may be reduced in several ways. Dr. Henri Laborit working at the Val de Grace Hospital in France has developed a technique for reducing body temperature solely by drugs. Total immersion in ice baths and application of ice packs also work.

Inspiration of cool air is another way to reduce body temperature. At least one commercial device exists that reduces body temperature by wrapping the patient in conductive blankets through which circulates a cold mixture of alcohol or glycol and water. Hypothermia has been brought about by refrigerating the blood externally and then forcing the cooled blood back into the patient. Until the present, however, no means has existed for inducing and maintaining a given level of hibernation automatically.

To meet this need, engineers at the J. B. Rea Co., in collaboration with the medical center at the University of California at Los Angeles, have designed and built a system known as the Reatherm. It will be used at St. John's Hospital in Santa Monica, Calif. by Dr. Muller and Dr. Damman in the treatment of severe cardiac cases. The experimental version of the system is shown in Figure 1.

SYSTEM OPERATION

The Reatherm controls patient temperature by closing a servo loop through the body of the patient as shown in Figure 1. A rectal thermometer—consisting of a thermistor encased in a silver tube and connected in a resistance bridge—serves as one temperature pickup element. A second thermistor bridge measures the temperature of the liquid flow entering the blanket itself. The sum of the voltages from these pickups is balanced against an input voltage from a calibrated potentiometer. The amplified difference between the input voltage and the sum of the thermistor bridge voltages drives a valve, which proportions the constant liquid flow in the blanket between a hot and cold supply. A limit to the maximum temperature differential between the patient and the blanket is assured by limiting the maximum temperatures of the hot and cold supplies to medically safe values.



Control system for cold anesthesia is closed through the patient's body. Fig. 1

TRANSIENT RESPONSE

The basic transient response is indicated in Figure 2. This data was obtained when the outer temperature loop was closed by placing the rectal thermometer in direct contact with the blanket surface and therefore represents the minimum response time of the system. When the outer temperature loop is closed through the body of a patient, the transient response is considerably modified because of the enormous thermal time lag of the patient. As a consequence, the temperature overshoot in Figure 2 does not occur when the blanket is wrapped around a patient.

As shown in Figure 2, the coolant temperature and patient temperature converge upon the control input setting. This does not give the optimum cooling rate. In practice, therefore, to insure the maximum cooling rate, the control input is set to 1 deg C and is not advanced to the desired patient temperature until the actual patient temperature has dropped to the value to be maintained. This sequence is shown in Figure 3.

This data was taken at the medical center of the University of California at Los Angeles where a 30-lb dog was used as a patient in preliminary tests of the equipment. These tests indicate that the equipment is suitable for clinical use as it stands.

COMPONENTS

A 45x28x43 -in. main cabinet contains the refrigeration system, the hot water system, the water reservoir, the pump, relief valve, mixing valve, a thermistor, the control motor, and the signal amplifier. Two smaller cabinets on top of the main cabinet house the thermistor bridges with their mercury cell power supplies and a vernier control input graduated in both the Centigrade and Fahrenheit scales. The maximum range of the control input is 1 to 39 deg C, although this

range is quite arbitrary and may be extended easily.

BLANKETS

The blankets are connected to the system by two 25-ft hoses which permit the main cabinet to be remote from the operation. The blankets are commercially available.

The mixing valve drive motor is controlled by relays. This type of control has been satisfactory, but a dc magnetic amplifier is under development to replace the control relays and dc vacuum-tube amplifier. This will decrease maintenance and increase the reliability and useful life of the Reatherm.

The mixing valve is a reworked shower head control. The cooling and heating systems are commercial items installed with minor alterations. The pump and its drive motor assembly were assembled from commercial components.

Patient temperature has been regulated within plus or minus ¼ deg C. This band can be narrowed easily to plus or minus 1/10 deg C.

Since doctors have little or no time to spend either monitoring or maintaining equipment, the emphasis is on stability, accuracy, and reliability.

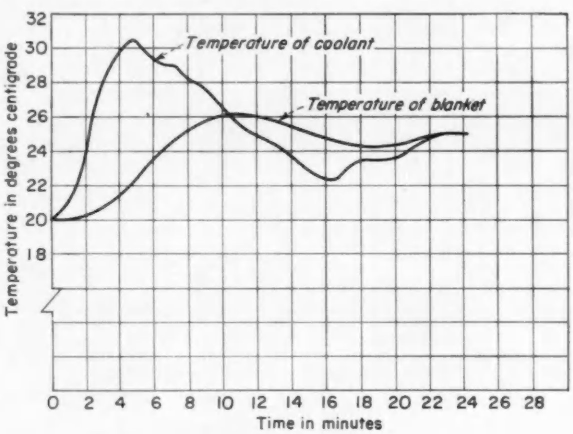
CALIBRATION

Calibration remains constant for several months at a time and is so simple that it may be checked and reset at the beginning of any operation with virtually no delay.

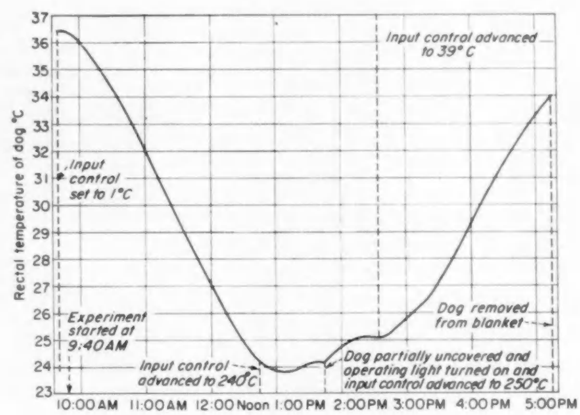
The equipment stabilizes and is ready for use one-half hour after the power switch is thrown. At the end of this half hour, the rectal thermometer may be laid on the cooling blanket. Both temperature reading meters should assume the same reading as the input control dial. If they do not, a simple screw driver adjustment on the front panel of the main cabinet will bring them into agreement.

Ease of operation was a prime design consideration. Only one adjustment of the control input cabinet dial setting is necessary. The system is virtually maintenance free. No special precautions are necessary either in starting up or in shutting down.

The coolant is circulated in a closed system; therefore, level need be checked only at intervals of several months.



Basic response of system without patient to a step input of 5 deg C. Fig. 2



Large thermal time lag of patient is indicated by clinical test on 30 lb dog. Fig. 3

Voltage Monitor Detects Any Change

An electronic circuit now being packaged for television receiver servicing may have many uses for the control engineer. The circuit was designed by Authorized Manufacturer's Service Co., Inc.

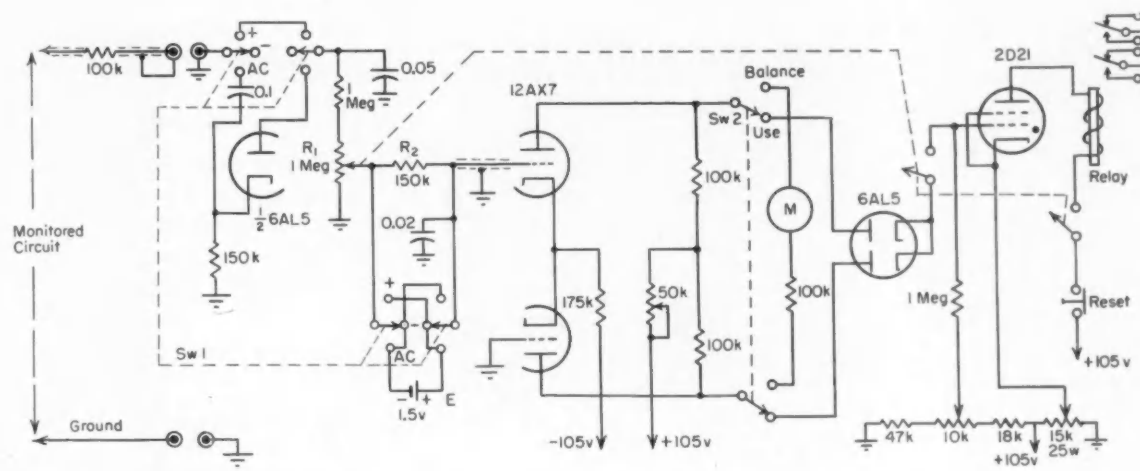
As diagrammed, the circuit will monitor any voltage from plus or minus 3 to plus or minus 500 vdc, as well as any ac voltage in the same range. Frequency response to ac is 40 to 30,000 cps. A relay closes if the monitored voltage varies by more than plus or minus 15 per cent.

In use, a portion of the input voltage (or its rectified equivalent in the case of ac) is selected by R_1, to balance the 1.5v from dry cell E that appears across R_2. This places the input grid of the cathode-coupled 12AX7 phase inverter at ground potential, balancing the inverter.

The phase inverter is operated between positive and negative supplies. When balanced, the plate voltages are equal and slightly less than the voltage on the 2D21 thyratron's grid. The 6AL5 will not conduct.

Unbalance of the phase inverter by a change of the monitored voltage in either direction will fire the thyratron.

Although the circuit's characteristics are satisfactory for its intended use as a TV service bench instrument, refinements are possible in many directions. It can be designed to monitor voltages less than .5v. The sensitivity can be increased so that a smaller change will actuate the relay.



As designed, the circuit must be reset manually, but automatic or remote reset is easy to build in.

In applications where all depends on the constancy of the power supply (computers, for one example), this circuit can be a godsend. It can sound a warning at malfunction or even switch in a standby source of power.

New Circuit Computes Tangents

PERRY A. SEAY, Reeves Instrument Corp.

Designed for use in dc analog computers, this new circuit computes tangents with a theoretical accuracy of more than 2 min even in the vicinity of 0 and 90 deg.

The circuit consists of a linear potentiometer, two fixed resistors, and a summing amplifier, Figure 1. With a high gain amplifier, the ratio of output to input voltage is equal to the ratio of feedback resistance, R_a, to input resistance, R_b. This ratio is expressed by:

$$\frac{e_o}{e_i} = -\frac{R_a}{R_b} = -\frac{(2.8-K)K}{(1.8+K)(1-K)} \cong -\tan\theta \qquad (1)$$

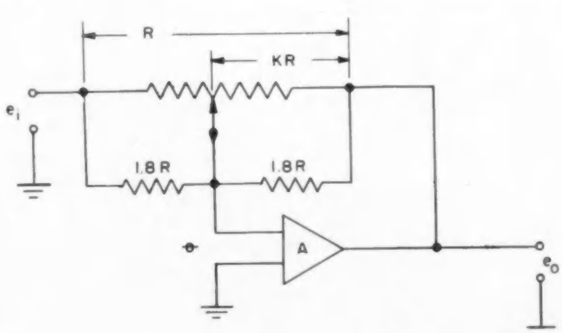
where θ in degrees is equal to 90K.

The error in this approximation, Figure 2, does not exceed 2 min for the entire range including the points in the vicinity of 0 and 90 deg. This does not include the error introduced by potentiometer inaccuracy, or that introduced by finite amplifier gain. A given per cent of full scale potentiometer error will produce a corresponding per cent of full scale angular error. Thus a 0.1 per cent potentiometer will introduce errors up to 0.1 per cent of 90 deg or 0.09 deg.

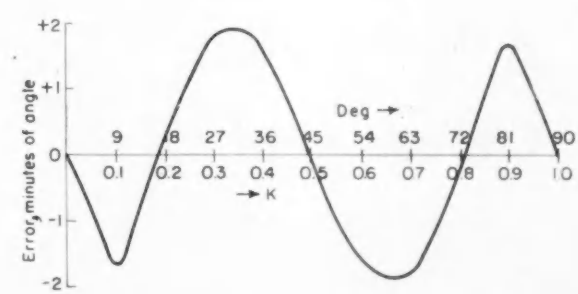
The error in the computed tangent can be determined by diffentiating Equation 1, and then dividing each side of the result by the respective sides of Equation 1. Thus,

$$\frac{d(\tan\theta)}{\tan\theta} = \left[\frac{2.8-2K}{(2.8-K)K} + \frac{0.8+2K}{(1.8+K)(1-K)}\right]dK \qquad (2)$$

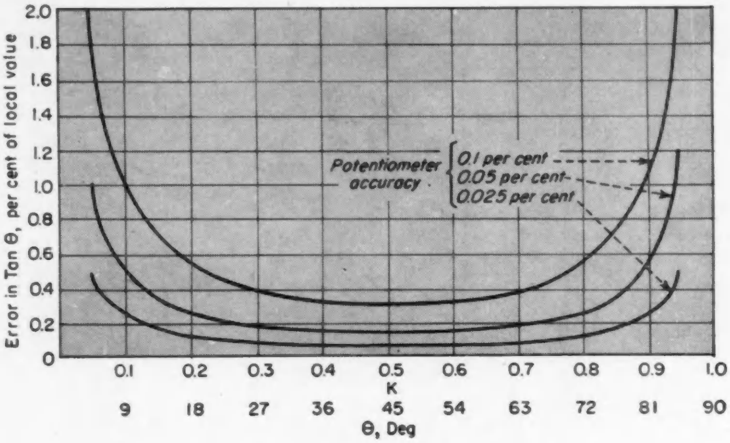
If dK is the per cent of full-scale error for the potentiometer, this expression gives the per cent error in the tangent. The results are plotted in Figure 3



Tangent computing circuit. Fig. 1



Error in minutes of angle for the approximation assumed in Equation 1. Fig. 2



Error resulting from potentiometer inaccuracy. Fig. 3

for several typical potentiometer accuracies.

These curves indicate rather large errors in the vicinity of zero. This results from the curves being plotted as per cent error with respect to the local values and not as per cent of full scale. The latter is impossible, because full scale is infinite so fas as the tangent is concerned. The absolute accuracy in the vicinity of zero is well within the requirements of most electrical analog computers.

An error is introduced because of finite amplifier gain. This can be calculated as follows. For amplifier gain, $-A$, the output voltage is

$$e_o = -Ae_g \tag{3}$$

where e_g is the voltage appearing at the arm of the potentiometer and the amplifier input grid. In terms of e_o and e_i,

$$e_g = \frac{e_iR_a + e_oR_b}{R_a + R_b} \tag{4}$$

Substituting the value of e_g from Equation 3 into Equation 4,

$$\frac{e_o}{e_i} = -\frac{R_a}{R_b + \dfrac{R_a + R_b}{A}} \tag{5}$$

This is the same as Equation 1 except for the right-hand term in the denominator. The fractional error introduced by this term can be determined by subtracting Equation 1 from Equation 5, then dividing by Equation 1 and simplifying

$$\frac{\Delta_a(\tan\theta)}{\tan\theta} = -\frac{R_a + R_b}{R_a + R_b(1 + A)} \tag{6}$$

Substituting Equation 1 into this,

$$\frac{\Delta_a(\tan\theta)}{\tan\theta} = -\frac{\tan\theta + 1}{\tan\theta + 1 + A} \tag{7}$$

When A is large compared to tan θ

$$\frac{\Delta_a(\tan\theta)}{\tan\theta} \cong -\frac{1 + \tan\theta}{A} \tag{8}$$

Multiplying this by 100 gives the per cent error. Thus, the error introduced by a finite amplifier gain is proportional to $1 + \tan\theta$. For example, at 45 deg the amplifier gain required to give 0.1 per cent accuracy is 2,000. At 89 deg an amplifier gain of 58,000 is required for 0.1 per cent accuracy.

A system error is introduced if the computer is operated from a source with a finite output resistance, R_o. This resistance adds to R_b and introduces an error in the tangent. It can be computed from Equation 1.

$$\Delta_b(\tan\theta) = \frac{R_a}{R_b + R_o} - \frac{R_a}{R_b} \tag{9}$$

Then:

$$\frac{\Delta_b(\tan\theta)}{\tan\theta} = \frac{R_a}{R_b + R_o} - \frac{R_o}{R_b} \tag{10}$$

Where R_o is small compared to R_b. The output impedance of most computing amplifiers is sufficiently low that the above source of error need not be considered except in the most exacting applications.

"AUTOMATION"

Choose your Meaning

Most of us talk like Humpty Dumpty. Remember, in "Through the Looking Glass," Lewis Carroll had him say: "When I use a word, it means just what I choose it to mean—neither more nor less."

When we write, however, we try to avoid using Humpty Dumpty words that mean whatever the reader chooses. That's why CONTROL ENGINEERING is leery of "automation," which may imply anything from conveyor-belt transport to the most complicated form of automatic control.

"Automation" is, nevertheless, barging into the English language. Curious as to what meaning it will ultimately take on, a friend of ours recently wrote the editors of the Merriam-Webster dictionary.

Associate editor Hubert P. Kelsey replied that "automation" had not yet made the grade, as far as Webster is concerned. But the lexicographers have a dosier on it, dating back to a reference taken from "American Machinist," October, 1948.

Mr. Kelsey explained: "On the basis of current usage . . . we submit the following definition protempore: "automation, n. 1. The act or technique of making a manufacturing process fully automatic. By this technique, parts are moved into and out of machines without being handled by human operators. 2. The state of being automatic. 3. Automatic operation, as of a machine."

More than ever, we're sure "automation" is a Humpty Dumpty word.

Automation

–your dream for tomorrow may be operating today!

Is completely automatic production your hope and goal? There is much reason to believe you can have it *now*. In industry after industry Cutler-Hammer engineers and Cutler-Hammer Automatic Control have transformed plans many would call visionary into astounding realities. Your dream for tomorrow may be operating today!

Automation may hold tremendous possibilities for your company in manufacturing economies and product uniformity. Others have found it so. But automation invariably requires huge investments in engineering planning and in the resulting equipment. The figures are always too large to permit gambling on the outcome. That is why you too should ask Cutler-Hammer engineers to participate in your earliest exploratory discussions.

Automatic electrical control is the very heart of automation. And Cutler-Hammer leadership in automatic control engineering and equipment has been recognized and respected for more than six decades. The unparalleled experience Cutler-Hammer engineers bring to a project frequently points the way to unsuspected automation possibilities, avoids costly false planning starts, and always safeguards against impractical or needlessly complex constructions. Your plans and all ensuing developments will be treated with the strictest confidence*. Write or wire today. CUTLER-HAMMER, Inc., 1467 St. Paul Ave., Milwaukee 1, Wis.

*The scope of Cutler-Hammer experience in automation has been indicated without specific identification of the installations in deference to the almost universal desire for confidential handling of such advanced developments.

AUTOMOTIVE

FLAT WIRE

CEMENT

TEXTILE

RUBBER

Completely automatic production lines each turning raw stock into fully finished automobile tires at the rate of nearly five tires per minute. Automation by Cutler-Hammer engineers and Cutler-Hammer Control equipment.

SUGAR

Completely automatic sugar refining. Multiple duplicate processing lines continuously repeat an involved sequence of operations, but are interlocked to prevent undesirable simultaneous recycling. Automation with Cutler-Hammer Control is complete in that the single operator for the entire plant has no routine supervisory responsibility.

GLASS

Completely automatic glass manufacture despite complex problem of non-uniform polishing time required within the work cycle. Automation by Cutler-Hammer engineers and Cutler-Hammer Control equipment.

PAPER

Complete automatic production from pulp to finished tissue. All drives synchronized and interlocked, but with the ability to regulate dry-end speed with respect to wet-end speed for control of product characteristics. Production is more than 500 miles of 68 inch sheet per day. Automation by Cutler-Hammer engineers and Cutler-Hammer Control equipment.

STEEL PIPE & TUBING

Two completely automatic mills for turning raw stock into finished tubular products for the oil fields. No. 1 Mill makes pipe up to 16" in diameter. No. 2 Mill makes pipe of 6⅝" diameter and smaller. 140 ac motors and 150 dc motors from 1 hp to 150 hp are used. 100% Cutler-Hammer Control; ac panel 112 feet long, dc panel 80 feet long, both 7½ feet high. Cost of control $500,000.

CUTLER·HAMMER

MOTOR CONTROL

C·H

NEW PRODUCTS

FREQUENCY RESPONSE test "package" rapidly plots transfer function of a system directly on a polar chart.

LISTING IN GROUPS

Control engineers have developed a fresh and healthy curiosity in recent years. They want to know the performance characteristics of the control equipment that they design, buy, and apply. They also want to know the inherent characteristics of a process or machine before they try to control it automatically.

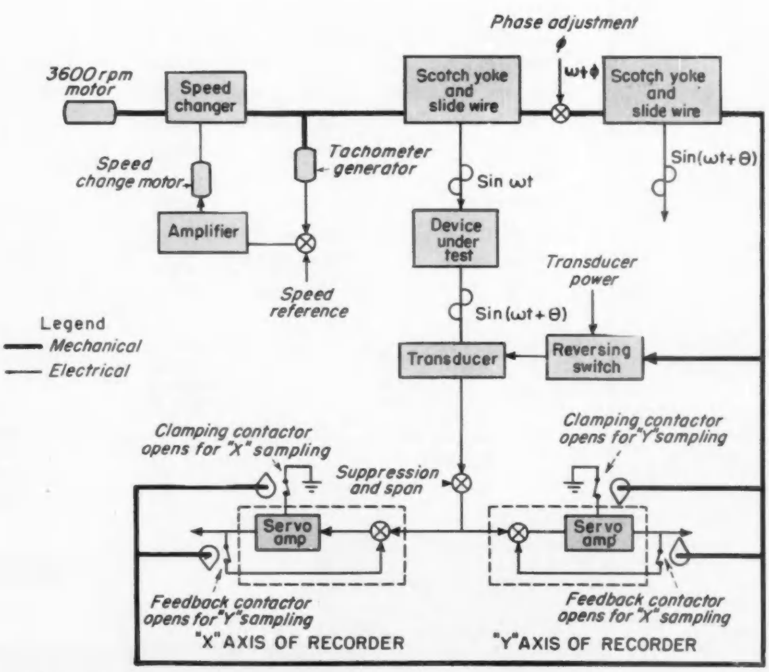
One of the outstanding analytical tools to satisfy this curiosity is the technique of frequency response. Basically, this is a way to evaluate the relationship between signal input and output of a device or system. The FR technique relies on a sinusoidal input and ultimate analysis of output curves. These curves, correlated mathematically with Nyquist's stability theory, make it possible to predict the performance of the device or system in actual closed loop operation.

Mechanized equipment set-ups have been developed to speed evaluations. The approach involved is to generate sinusoidal test signals in place of the normal input of a physical system. But the equipment does not go on to automatically plot system data.

At the recent International Instrument Exposition, Minneapolis-Honeywell exhibited what appears to be the first complete "package" to apply the FR technique and plot a ready-made Nyquist diagram directly on polar paper. This ingenious instrument system has three basic elements:

1. a mechanical sine-wave generator for pneumatic, electric, or positional signals.
2. a function plotter, consisting of a dual-circuit strip-chart electronic recorder, which resolves X-Y functions directly on polar paper.
3. a high-speed two-pen strip-chart recorder, which registers input and output signals.

The block diagram shows how the system works. An input frequency is developed from a variable-speed motor shaft drawing voltage from a portable potentiometer as reference signal. This shaft rotation is converted to pneumatic, electrical, or positional signal by suitable transducers. The signal is then fed to the device being tested, and its output is converted to a 60-cycle carrier voltage by a suitable transducer such as a slidewire or strain gage.



BLOCK DIAGRAM OF THE SYSTEM ▲

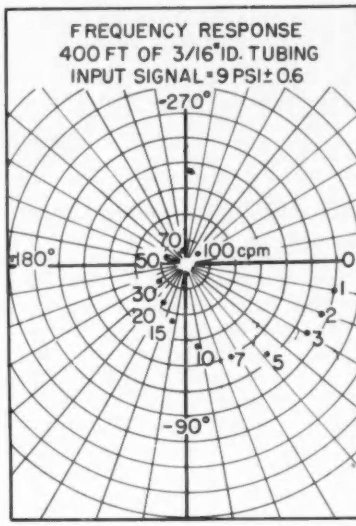
The voltage is then applied to the function plotter, which plots a vector corresponding to the output sine wave.

TWO BALANCING SYSTEMS

The function plotter actually contains two complete self-balancing measuring systems and the output from the device under test is fed to both systems. Resolution of the X and Y components involves a sampling of the output wave by switches that are driven synchronously from the signal generator shaft. These short the balancing motors except during sampling interval. By adding measured voltages, summing resistors develop an error signal during sampling and so reposition the balancing motor.

The signal generator covers a range of from about 1 cycle per hour to 10 cps. The desired frequency is set by a calibrated pot and held by a speed servo. In addition to test signals, it can generate reference and timing signals.

A sample polar plot is shown. This



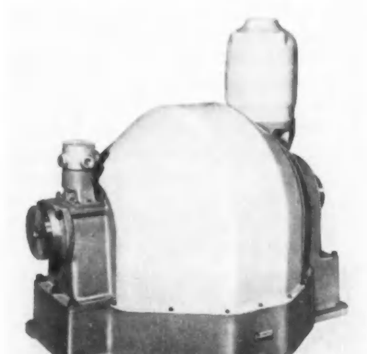
represents the actual frequency response of 400 ft of $\frac{3}{16}$ in. tubing dead-ended directly into a pressure transducer. The frequencies corresponding to points on the curve cover the range from 0 to 50 cpm. Input to the tubing at all frequencies shows up on the plot as the point 3i. The total plot indicates that the tubing imposes a phase shift of 200 deg and an amplitude ratio of 0.13 at a frequency of 50 cpm.

Curves such as this can be drawn in as little as 8 min. Similar charts shed light on the frequency response characteristics of servomechanisms, process capacities, actuators, control instruments, and various units in a processing line. The system can be used also for analog testing and general trouble shooting in research and development as well as in plants.

Honeywell took several years and a formidable amount of man-hours to fully develop this specialized test system to handle its own problems. The company is to be lauded for making it available to industry at this time. Minneapolis-Honeywell Regulator Co., Industrial Div., Phila. 44, Pa.

Circle No. 1 on reply card

FLOW MEASURING instruments are developing at a rate proportional to industry's rapid transition from batch to continuous processes. Here are three new approaches to special flow-gaging problems.

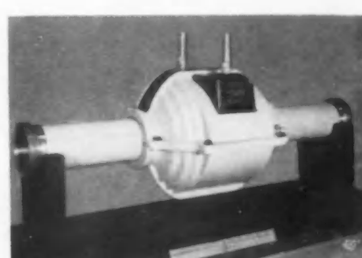


GYRO MASS METER gages fluids on a direct weight basis.

This novel approach to flow measurement works on the gyroscopic principle. Fluid is sent through a specially shaped pipe coil which is rotated in an enclosed housing (see picture) by a constant speed drive. The gyroscope-like angular momentum of fluid is picked up through a restraining spring torque, which is converted to a proportional ac voltage by an output signal generator.

The utility of this measurement is obvious. Here the fluid is weighed as it flows. Meter accuracy is thus independent of pressure, temperature, and viscosity change. Its accuracy and linearity suggest it would be excellent for precise batching and proportioning control, as well as in materials balance and test studies. The maker has already made great progress in supplying integrated control panels as a packaged approach to flow problems of this type. Control Engineering Corp., Norwood, Mass.

Circle No. 2 on reply card



ELECTROMAGNETIC METER copes with unusual flows.

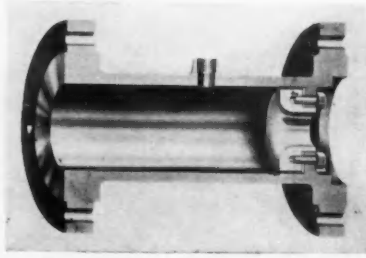
Faraday's principle of electromagnetic induction is updated for control engineering in this nicely designed and compact flow transmitter. Essentially, the unit consists of a section of pipe surrounded by coils of an electromagnet. Two electrodes—with top connector terminals seen in the picture—are flush-welded into the in-

ner surface of the pipe. Movement of fluid through the pipe and its magnetic field thus induces a voltage across the two electrodes which is proportional to flow. This, in turn, is amplified and accurately read remotely.

A significant application for the new meter is in handling food liquids. Here its straight-through construction makes it easy to keep clean. Also, the meter should be excellent for viscous and corrosive fluids, because it is unaffected by pressure, viscosity, density, and conductivity changes and can be made of resistant metal.

The maker offers the unit in pipe sizes from 2 to 8 in. Error is limited to less than one per cent of scale span from maximum down to zero flow. Pressure drop is simply equal to the straight pipe length. *The Foxboro Co., Foxboro, Mass.*

Circle No. 3 on reply card



UNIT PRESSURE meter simplifies gas gaging.

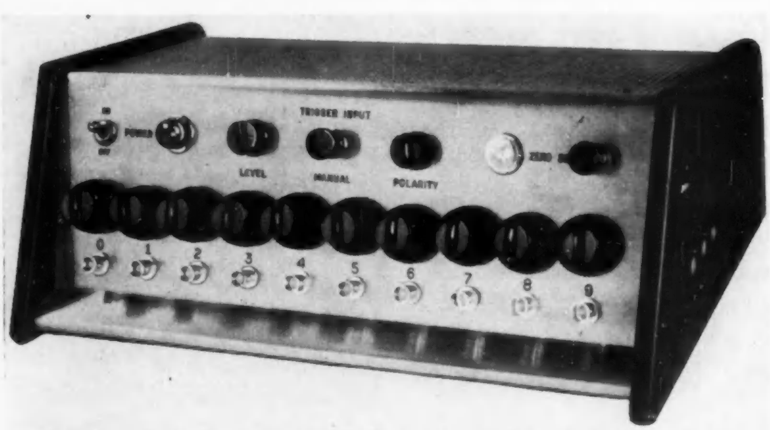
Here is a simple way to measure flow that has been well known as a method, but—up to now—unexploited commercially. Essentially, the flow pickup pictured puts a sturdy restriction in the flow line and gages the pressure upstream as a direct index of flow. This will only work when the ratio of absolute pressure downstream is equal to or less than the so-called critical-pressure ratio for the fluid involved. Thus the fluid moves through the nozzle throat of this device at sonic velocity. Downstream pressure variations do not affect its rate of flow.

It's obvious that a simple pressure indicator or recorder can be used with this primary element to measure and control flow. This uncomplicated system can be applied to meter or proportion process steam or gases with desirable dynamic characteristics.

The new metering assembly is available in pipe sizes from 2 to 10 in. and for pressures up to 900 psi. It can handle flow rates up to 300,000 lb per hour of dry and saturated steam. Its accuracy is about 99% of full scale reading. *King Engineering Corp., Ann Arbor, Mich.*

Circle No. 4 on reply card

ELECTRONIC CONTROLS have demonstrated new possibilities for faster response, greater precision, and all-around flexibility in system design. Following are some new electronic components now available for automatic control.



ELECTRONIC SWITCH fits a single oscilloscope for analysis jobs that usually require ten.

The picture shows a compact nine-knob box with a formidable function. It takes as many as ten input wave forms and marshalls them into a single, sequenced wave train. It then chops the train into ten separate sweeps which will register down the face of a single gun scope. And it can throw these sweeps at the scope at 500,000 per sec.

This device will delight researchers who want to compare ten related phenomena at one time. They could, of course, run back and forth down a line of ten scopes to do the job, too. It suggests, for example, a new approach to body strain measurements, interrelating TV signal patterns, and multi-organ response in animal metabolism.

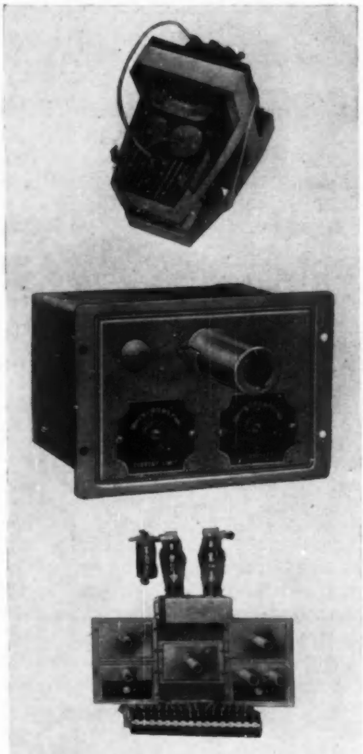
Secret of this high-speed electronic switch is its unique beam-switching tube. This triggers the triode amplifier tubes which are fed with the various wave forms or pulse patterns. The output crosses a common load resistor to form a single wave train, which contains all the input wave forms in sequence. The vertical deflection plates of the scope then space each wave form separately down the face of the viewing tube. *Burroughs Corp., Electronic Instruments Div., Phila., Pa.*

Circle No. 5 on reply card

BUILDING BLOCKS created for control system design.

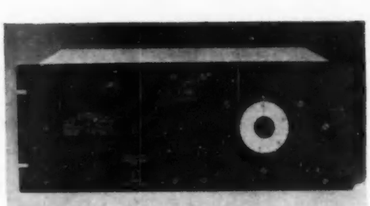
Sealed in plastic and encased in metal, these electronic "packages" are designed to simplify the piecing together of a system and speed its maintenance. The pictures show how it works. At the top, the component

parts for a "package" are assembled and wired. Middle item is the sealed, encased assembly. And the bottom displays a complete electronic regulator with several of these component "packages" in place.



This novel approach to control design is intended to increase the value of the maker's own line of motor controls. It may be, however, that this manufacturer could be coaxed to furnish this "building block service" to outsiders too. *Reliance Electric and Engineering Co., 1088 Ivanhoe Rd., Cleveland 10, Ohio.*

Circle No. 6 on reply card



AUTOMATIC VOLTAGE regulator servos its output.

A proportional-control servomechanism in this voltage regulator increases its accuracy and transient response. Thus it is an ac line-voltage stabilizer that should interest control system designers. For although it responds almost like a saturable-core reactor or vacuum tube system, it adds no power-factor restriction or harmonic distortion to input voltage.

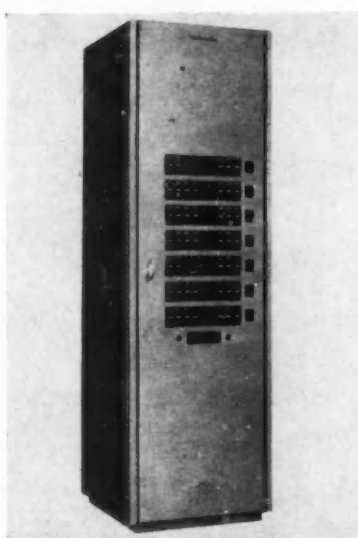
Basically, this new regulator consists of a Variac autotransformer that adjusts output voltage, a buck-or-boost step-down transformer to multiply power rating of this Variac, and a servomotor to position the Variac.

Characteristics

Capacity .... 6 kva
Accuracy. . less than 0.25 per cent error
Efficiency .... 98 per cent
Adjustment Range. . plus or minus 10 per cent from a 115 v base (or 230 as special)
Response .... 10-40 v per sec

General Radio Company, 275 Massachusets Ave., Cambridge 39, Mass.

Circle No. 7 on reply card



SUPERVISORY CONSOLE uses tone signals for telemetering.

The push buttons and signal lights on this console operate and signal the position of such remote devices as pumps, valves, circuit breakers, and motors. It does this by originating and receiving a stable tone code using a resonant generator and a companion resonant relay receiver. These signals can be fed into any type of communication equipment able to carry audio signals, as well as via carrier lines.

A special feature of the system is its ability to first check, by pushbutton and dual coded signal, actual position of whatever it controls. When this shows up, as a signal light, the "operate" button then can be pushed. Another feature is an integrated light flashing alarm system that tells the operator the remote device has been moved to an unorthodox position.

As many as 90 different remote points can be supervised from this panel, using twelve different tones. The system can be used also for selective telemetering of instrument-registered process variables. *Motorola Communications and Electronics Inc., 4501 Augusta Blvd., Chicago 51, Ill.*

Circle No. 8 on reply card

MICROWAVE TESTER tackles bench, line, or field job.

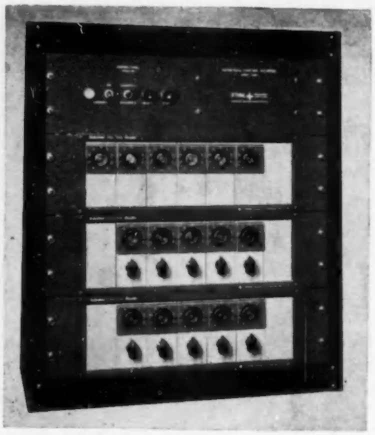
This compact instrument seems to have just about every function the man testing microwave equipment could want. It can measure power wave form, and frequency. It enables viewing and analysis of transmitter spectra as well as bandwidth characteristics. And it will generate signals.

Characteristics

Signal Generator. . . Continuous wave, square wave, FM, RF, 8.5 to 10 kmc
Power Monitor. . meas. average power of 8.5 to 10 kmc signals with error less 2db full range
Spectrum Analyzer. . . 8.5 to 10 kmc displayed on 3 in. CRT
Wavemeter. . . reaction cavity type, 8.5-10 kmc error less than 0.03 per cent
Power Supply. . . single supply furnishes all necessary ac and dc voltages primary power is 50 to 1200 cps
Size .... 17 x 10¼ x 13 in.
Weight .... 45 lb

Kearfott Co., Inc., Van Nuys, Calif.

Circle No. 9 on reply card



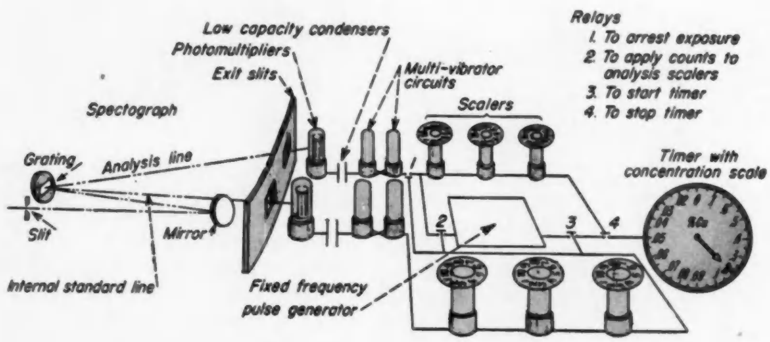
COUNTING UNITS mount together in functional strips to build up highly specialized counters.

Here is a clever way to build up an electronic counter with functions tailor-made to your application. The picture shows three decks of counting tubes surmounted by some control switches. Actually each tier consists of five individual counter units, which have been simply slipped into the chassis as desired. These units can function in decade, preset, duo-decade, and register jobs. The maker estimates that at least fourteen different functional strips can be built up from the combination.

Some characteristics: speeds of 20,000 cps or more; low current, low heat, cold cathode tubes; strips are plug-in type with only 2 x $5\frac{1}{4}$ in. facing. It is claimed that counters assembled this way actually cost less than existing units, yet do more specialized jobs. *Atomic Instrument Co., 84 Massachusetts Ave., Cambridge, Mass.*

Circle No. 10 on reply card

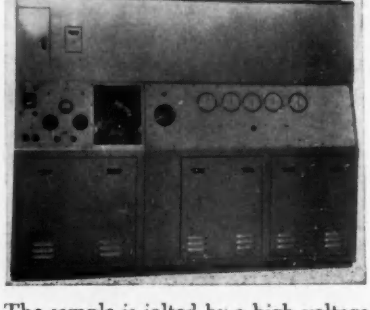
UNUSUAL INSTRUMENTS



SPECTROMETER SERVES UP direct qualitative or semi-quantitative analysis in per cent concentration.

A patented feature of this new direct-reading spectrometer are the twin collimating mirrors that produce two identical spectra, one above the other, at full intensity. Thus, in measuring two adjacent lines, the instrument feeds spectral light directly into individual photomultipliers without first detouring it through deflecting systems. These innovations, it is claimed, make it possible to analyze a sample completely in less than one minute—and with a standard error of less than 2 per cent.

The diagram shows how each of the five indicating channels produce data.



The sample is jolted by a high voltage spark, and radiations pass through slit, off of mirror, and finally through Wadsworth 1.5-meter grating, which disperses them. Parallel photomultiplier circuits in a plug-in chassis receive the standard and the analysis spectrum lines. Current from these photomultipliers charges a condenser, and its discharge is pulsed through a multivibrator circuit to glow discharge tubes of a scaler. The scaler ends up with a count proportional to light intensity. When the standard, or matrix, scaler part of the system reaches a count of 1,000 the source is shut off. Hence the difference between 1,000 and N, the reading of the analytical scaler, is an inverse measure of element concentration in that sample.

To convert this difference into a direct concentration reading, a 60-cycle pulse generator continues to build up the count on the analytical scaler until it reaches 1,000. Meanwhile, a timer keeps pace with the generator. When the count reaches 1,000 the timer shuts off. The deflection on the timer scale (a measure of 1,000-N) can be calibrated against the concentration of the element being measured. Each of the five channels has its own timer and pulse generator.

All this functional and ingenious circuitry is housed in an $81\frac{1}{2}$-by-$43\frac{3}{4}$ in. metal cabinet with unitized plug-in components for individual channels. *Jarrell-Ash Co., Newtonville, Mass.*

Circle No. 11 on reply card

SPECTROPHOTOMETER plumbs neglected spectrum region.

This recording spectrophotometer works in the near-infra-red portion of the spectrum—a neglected area in spectrochemical analysis. And its maker claims that its cost and performance cannot be matched by conventional infra-red instruments.

A quartz monochromator and sensitive lead sulfide cell are basic elements in the unit. These are coupled with a double-beam ratio system using a single receiver and for ultra-violet work a photomultiplier detector.

Characteristics

Wavelength range	220 to 2700 mu
Resolution	0.1 mu at 220 mu
	2.5 mu at 1000 mu
	5.0 mu at 2500 mu
Scanning Speeds	5, 15, 50, 150 or 500 min
Stray Light	less than 0.2 per cent 0.2-2.5 u

Beckman Division, Beckman Instruments, Inc., Fullerton 1, Calif.

Circle No. 12 on reply card

GRAPHIC RECORDER plots with inexpensive dexterity.

Here is a modestly priced bench recorder that comes in two pieces so that it can be set up for polar plotting, multi-channel, or 8-by-10-in. loose leaf graph paper recording. Top section in the picture contains the servo-driven pen. Lower section with standard strip chart drive can be replaced with these other chart drives.

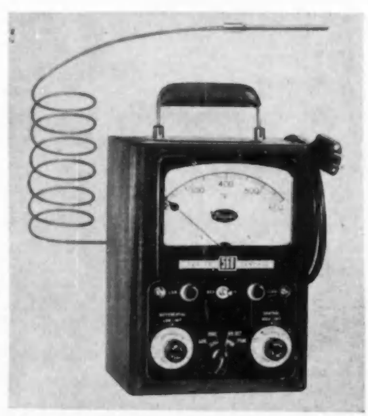
This new recorder should be a versatile research and test tool. It can graph any variable that can be represented by a millivolt dc signal. Further, its paper drive can be mechanically coupled and synchronized to record such special functions as frequency response and diode characteristics.

Characteristics

Input Resistance	½ megohm
Fullscale Sensitivity	100 mv
Pen Response Speed	1 in. per sec
Chart Speeds	4 in. per min to 1 in. per hour
Size	servo recorder is 3 x 6 x 10 in.
Power	35 w, 115 v, 60 cps

Hazatrol Corporation, 215 Market St., San Francisco, Calif.

Circle No. 13 on reply card



THERMISTOR-ACTUATED indicator senses speedily, simply.

This new temperature indicator owes its compact size, good stability, and high sensitivity to the thermistor. The manufacturer claims it is the first such instrument specifically designed to use this sensing element.

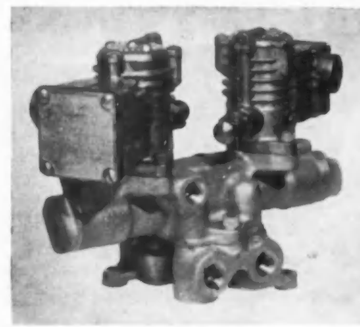
Characteristics

Range	0 to 600 deg F
Accuracy	0.25 per cent full scale
Control	on-off and time-proportioning electric contact
Differential	0 to 10 degrees
Lead Length	200 feet

Fenwal Inc., Ashland, Mass.

Circle No. 14 on reply card

CONTROL VALVES



DOUBLE SOLENOID eliminates need for holding relays.

Here is a four way valve with its stem positioned by two pilot-operated solenoids. The advantage is that any momentary energizing of a solenoid reverses the position of the main stem. This eliminates the need for holding relays in the electrical circuit. Once positioned, the stem will remain static until the other solenoid is energized to reverse its position.

The new unit comes in basic ⅜ and ¾ in. sizes. It is compact, measuring only 3 x 5 x 8 in. It has options for a manuual override in both directions and an external pilot supply. The valve permits conversion of standard 35- to 200-psi operation to low pressure or vacuum, as well as to pressures as high as 300 psi with a separate supply to the pilot valve. *Valvair Corp., 454 Morgan Ave., Akron, Ohio*

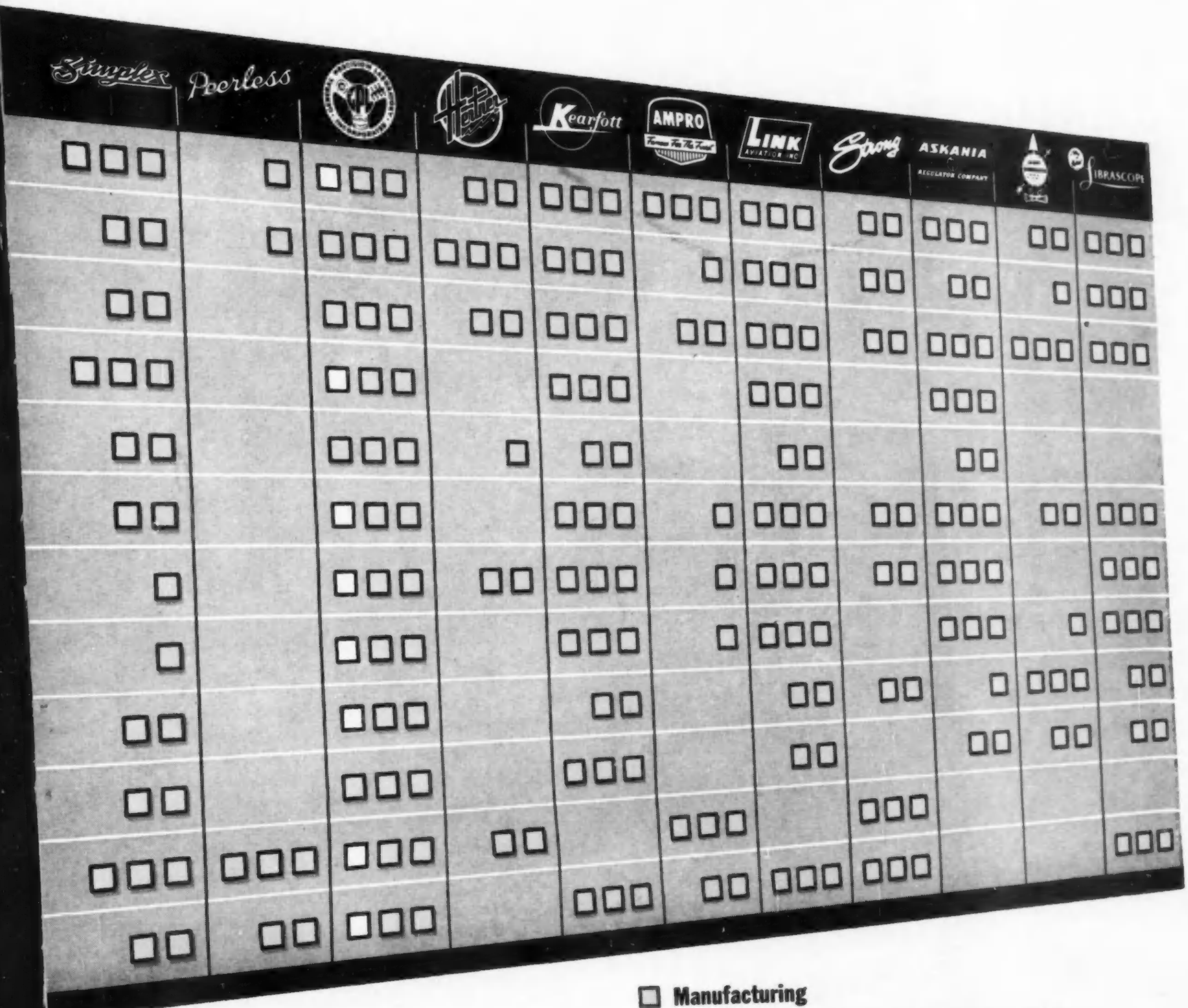
Circle No. 15 on reply card

FEEDBACK FACT

Posed: Some way to control brightness of fluorescent lighting.
Solved: General Electric has adapted an old lighting principle to combine electrical controls with a special, rapid-start ballast.

One of a series telling
how the producing companies of
General Precision Equipment Corporation
are contributing to America's progress.

precision technology



□ Manufacturing

□□ Manufacturing and product development

□□□ Manufacturing, product development and research

□□□ Pilot manufacturing, product development and research

AMPRO CORPORATION
CHICAGO

LINK AVIATION, INC.
BINGHAMTON, N. Y.

THE STRONG ELECTRIC
CORPORATION—TOLEDO

ASKANIA REGULATOR
COMPANY—CHICAGO

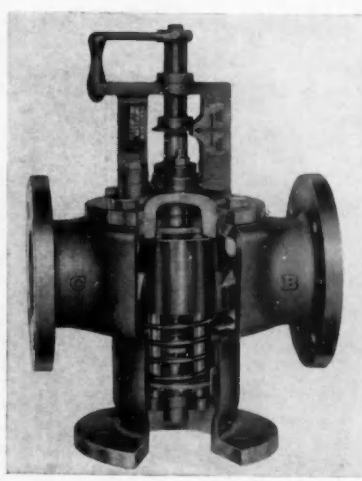
BLUDWORTH MARINE
NEW YORK

LIBRASCOPE, INCORPORATED
GLENDALE, CALIFORNIA

PACKLESS SOLENOIDS do many chores in small space.

The overall size of this new line of compact solenoid valves (normally closed) is 3 13/16 in. high and 2¾ in. face to face. Yet the valves can handle a maximum pressure on air of 200 psi and are available for ⅜, ½, ¾, and 1 in. pipe sizes. The valves have packless construction, work on all standard ac and dc voltages with a 10w power consumption. Added optional features: adjustable bypass; mounting brackets; ½-thread conduit connection. *Automatic Switch Co., Orange, N. J.*

Circle No. 16 on reply card

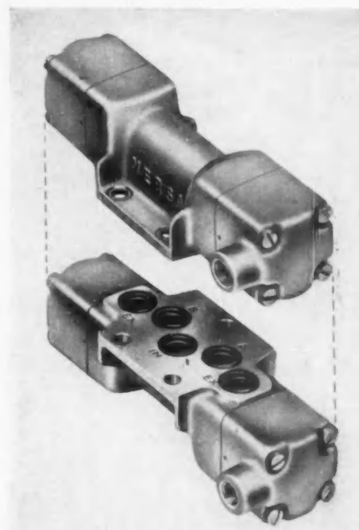


PLASTIC 'STAT pushes this valve stem up and down.

Ingenuity continues to flower in the valve field. The three-way temperature-control valve pictured is powered by the temperature response of a wax-like compound inside its spring area. When heated by the flow medium, the stuff melts and expands. This generates many times the force of an ordinary thermostatic pilot. The material resolidifies on cooling.

Advantages of the valve are its independence of internal system pressures and its small size and low cost. It is available for pipe sizes from 2 to 6 in. and can be set for temperatures in 10-to-15 deg increments over the 120-to-190-deg F range by substituting various "power pill" units. *Fulton Sulphon Div., Robertshaw-Fulton Controls Co., Knoxville, Tenn.*

Circle No. 17 on reply card



MANIFOLD MOUNT valves seal direct with O-rings

To mount this valve simply drill holes corresponding to its ports directly into a smooth flat manifold surface. Then bolt the valve into place. Port O-rings between valve and mounting surface act as a tight seal. The maker claims that it is impossible to cut these seal rings in the normal operating range of from 0 to 200 psig.

Because the design eliminates pipe or hose connections, it should save space and improve the appearance of machinery control systems. The valve can be actuated by hand, cam, foot, or pilot devices and can be spring-returned or spring centered. It is available with ⅛, ¼, ⅜, or ½ NPT size ports. The ¼ in. valve measures approximately 6 x 1½ x 2 in. *Versa Products Co., Inc., 249 Scholes St., Brooklyn, N. Y.*

Circle No. 18 on reply card

For Improved and More Compact Circuits!

Sylvania's versatile new

POWER TRANSISTOR 2N68

Here's a simple, rugged unit which provides an efficient solution to numerous power requirements including: Servo systems, control applications, and compact radio receivers.

This versatile Sylvania development permits 2.0 watts dissipation with no external heat sink. Its power gain is better than 15 db. And, it may be mounted in any position, with lead wires soldered or clipped for socket mounting or it may be bolted directly to the chassis (heat sink). For further details and technical data, write today to Dept. 4E-5211, Sylvania.

Electrical Ratings

Collector Voltage	−25 volts
Collector Current	−1.5 amps.
Dissipation (Free Air)	2.0 watts
Dissipation (Heat Sink)	4.0 watts

Note: Cooling structure is at collector potential

Typical Operating Conditions

Push-Pull Class B Amplifier. Grounded Emitter Circuit

Collector Supply Voltage	−12 V.
Collector Current (Maximum Signal)	−550 ma.
(Zero Signal)	−1.0 ma.
Generator Resistance	50 ohms
Input Resistance	50 ohms
Load Resistance (per Collector)	12 ohms
Power Output	5 watts
Gain	15 db

Another reason why it pays to specify Sylvania

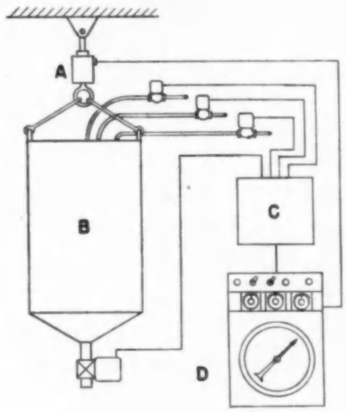
SYLVANIA

Sylvania Electric Products Inc., 1740 Broadway, New York 19, N. Y.

In Canada: Sylvania Electric (Canada) Ltd., University Tower Bldg., St. Catherine Street, Montreal, P. Q.

LIGHTING · RADIO · ELECTRONICS · TELEVISION · ATOMIC ENERGY

SOME SYSTEMS

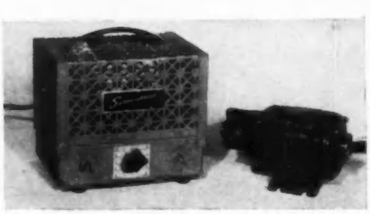


BATCHING SYSTEM relies on suspending load cell.

The diagram shows a new integrated-program batching system for liquids and bulk materials. A strain-gage load cell (A) supports the tank or bin (B). This is hooked to an electronic recorder-controller (D) to convert the signal to desired functions, which then pass through a control relay box (C) for proper sequencing of valve or feeder operations.

Systems are available to batch from a few pounds to several thousand pounds and from one to twelve feed streams. Selection dials on the instrument are graduated in pounds or percentage weight of ingredient to the batch. Push button operation and automatic repeat cycles are possible. *Gilmore Industries, 5713 Euclid Ave., Cleveland, Ohio*

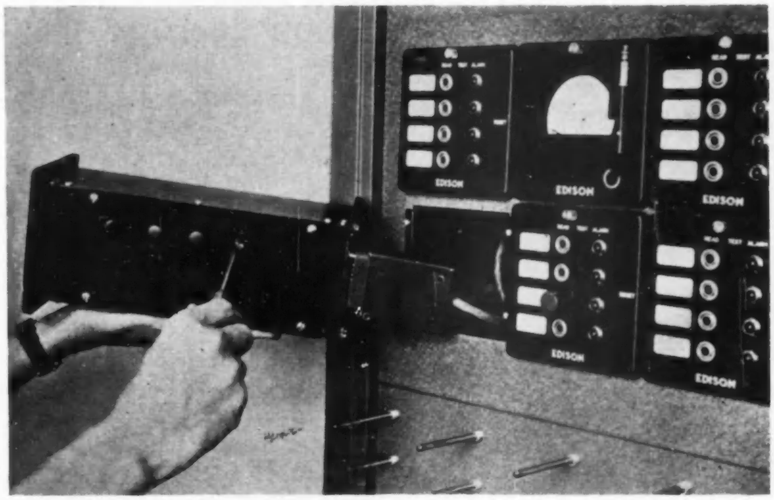
Circle No. 19 on reply card



MOTOR-CONTROL system offers laboratory precision.

This motor-control setup can accurately rotate sub-fractional horsepower motors at speed ranges as low as .08 to 1.6 rpm. It has a gearmotor reduction ratio of 1120:1, with a minimum speed range at constant torque of 20:1. Motors are available from 1/400th to 1/36th hp; all motor base speeds at 1750 rpm. *Electro-Devices, Inc., 4-6 Godwin Ave., Paterson, N. J.*

Circle No. 20 on reply card



TEMPERATURE MONITOR safeguards with at-site packaged "building blocks".

Here seems to be a simple yet highly effective solution to low-cost monitoring of critical temperatures in machinery and processes. Resistance bulbs are mounted at mulitiple sites. These in turn are connected, in banks of four, to neat little black boxes in a nearby panel containing four sensitive balanced bridge relays. Red light bulbs on each box tell when a temperature is excessive. Central to a group of these monitor boxes is an indicator with plug-in jack for spot reading of the runaway temperature.

This "building block" system has advantages over conventional temperature scanning. For one thing, all temperatures are under constant survey with no lapse scanning time. Further, wiring is kept to a minimum, since central panel warning can be drawn off from a bank of these monitors by a single wire connector. Finally, it is easy and inexpensive to build up this sort of system.

Ranges available run from minus 100 to approximately 1,350 deg F. Temperature alarm settings for each bank are made with a screwdriver adjustment. Installation costs are claimed to be 25 per cent less than for any other system performing the same function. *Thomas A. Edison, Inc., West Orange, N. J.*

Circle No. 21 on reply card

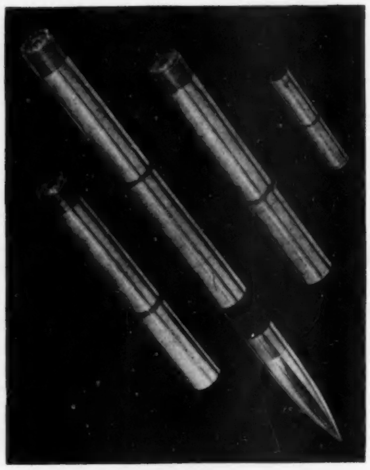
FEEDBACK FACT

Posed: A system that prevents railroad cars from smashing into each other while being coupled.

Solved: Westinghouse Air Brake has a new track-located weighing pickup that determines a car's inertia with the help of radar. A computer, fed with this information, regulates braking speed so the cars couple without crashing.

NEW PRODUCTS

PRESSURE TRANSDUCERS



AIR-BLAST GAGES unveiled for non-military use.

Previously tightly classified for military research, this interesting line of barium titanate piezoelectric transducers is now available for some imaginative use by industry in transient pressure measurements.

Here's what they can do. The pencil shaped one in the picture is streamlined to register transient shock pressures where fluid flow problems complicate the measurement. Its frequency response is flat to within 2 db over a range of 1 to 80,000 cps. This gage will withstand a static pressure in excess of 500 psi and a transient pressure of around 1000 psi.

The cylinder shaped gages were specifically designed for time-of-arrival shock measurements in blast studies. These also have flat frequency responses over the ranges of within 0.5 to 20,000 cps.

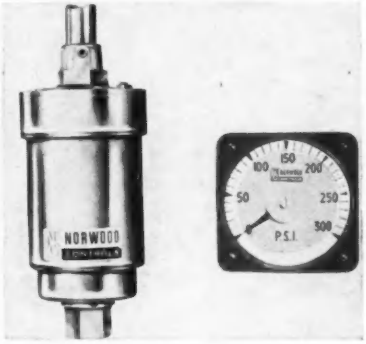
Inside this gage is a barium titanate cylinder coaxially mounted on a spindle and molded inside a waterproof neoprene sheath. Its large voltage response (0.1 to 0.2 v per psi) permits fairly simple associated equipment. *Atlantic Research Corp., Alexandria, Va.*

Circle No. 22 on reply card

ROTARY TRANSDUCER for pipe or vessel mounting.

Military measuring problems spawned this industralized signal generator. It's a high-resolution, electromagnetic, rotary transducer with linear output and has been designed—complete with remote indicator—for direct pipeline or process mounting.

This transducer is set up to measure either pressure or temperature. The pressure model has a twisted bourdon tube, which rotates the signal generator a minute amount to produce a proportional electric signal. A built-in bi-metallic ribbon spiral picks up temperature.



Some features of the system: explosion-proof housing; 100 per cent overload design; high output without amplification. *Control Engineering Corp., Norwood, Mass.*

Circle No. 23 on reply card

FEEDBACK FANCY

Needed: A way to speed the collection of weather data so forecasters can keep ahead of rapid meteorological changes.

Suggested: Why not have meteorological balloons telemeter their observations directly to forecasting centers equipped with high-speed computers? The current system—collect data, teletype it, evaluate it—is too slow.

Look to Cppc for Synchro Progress

FOR IMMEDIATE DELIVERY!

Actual Size
SIZE 10
.937" diameter

Actual Size
SIZE 11
1.062" diameter

Actual Size
SIZE 15
1.437" diameter

Next

SIZE 22

2.161" diameter

Next

SIZE 8

.750" diameter

CLIFTON PRECISION now offers these high accuracy, low weight synchros in practically every type of size 10, 11 and 15 as stock, off-the-shelf items for immediate delivery.

Also, virtually any variation of these same units is obtainable. For example:

- Synchros wound to customer's specific requirements
- Special shaft lengths and shapes
- High impedance units
- Feed back windings
- Special core materials
- Linear generators

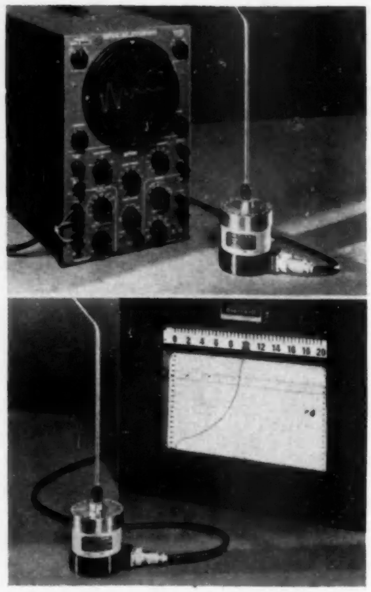
For customer's special application:

- Flux valve couplers—very low flux levels
- 30∽ to 5000∽ use (phase shifters)
- Sawtooth wave use—usable up to 100,000∽ or higher with special windings
- Computer elements with high accuracy, high linearity

Although we are prepared to serve your special needs, we urge the use of standard units wherever possible for speed of delivery and economy to you.

For full information, drawings etc., write or telephone: T. W. Shoop, Sales Mgr., Clifton Heights, Pa. MAdison 6-2101 (Suburban Phila.)
West Coast Rep. Wm. J. Enright, 988 W. Kensington Rd., Los Angeles. MUtual 6573.

Cppc
CLIFTON PRECISION PRODUCTS CO. INC.
CLIFTON HEIGHTS PENNSYLVANIA



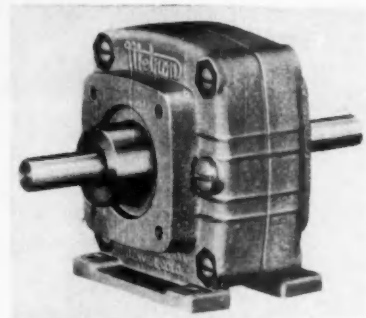
PRESSURE TRANSMITTER has uniquely rigged strain gages.

Design of this new industrial electrical pressure transducer is novel. Inside its stainless steel housing is a thin stainless contact diaphragm which acts on a lightweight piston that directly engages the sensing element. The sensing element consists of a metal ring with two strain gages bonded on its outer surface and two on its inner surface. The ring, under piston stress, acts as an elastic member. Electrical unbalance of the strain-gage bridge is a function of flex and tension.

The transmitter has a natural mechanical frequency exceeding 200 cps in the 100 psi range. It is insensitive to accelerations in two horizontal planes and vertically, with less than 0.3 per cent per full scale per g. Spurious response to shock or heavy vibration is less than one per cent of full scale. *Tabor Instrument Corp., N. Tonawanda, N. Y.*

Circle No. 24 on reply card

MINIATURE COMPONENTS

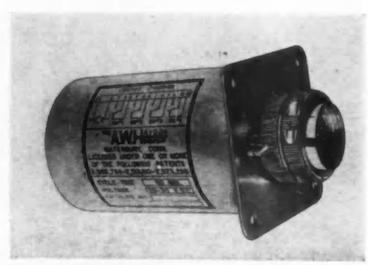


SPEED REDUCERS are diminutive but doughty.

Over 600 different ratios are available in this hockey-puck sized speed reducer—it measures only $2\frac{7}{16}$ in. high and $2\frac{3}{8}$ in. wide. The design is rated at $\frac{1}{10}$ hp, and includes 48 pitch gears. Shaft size is $\frac{5}{16}$ in., and bearings are anti-friction.

The compactness of this powerful speed reducer recommends it for the close confines of computers and servomechanisms as well as for chart drives in instruments. *Metron Instrument Co., 432 Lincoln St., Denver 9, Colorado.*

Circle No. 25 on reply card



TINY TIMERS work over wide range.

Here is a remarkably compact repeat-cycle timer which is motor driven. The whole works is fitted inside a

FEEDBACK FACT

Posed: A weapon that will weed out "tramp" fish infesting game-fish waters.

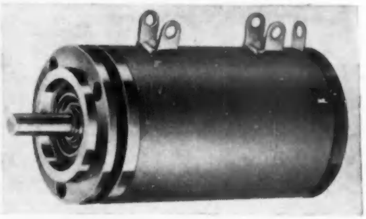
Solved: Workers at the University of Florida Sanitary Research Lab discovered that different voltages kill different fish. They're thinking of calibrating piscatorial pests and installing selective electrocution traps in streams.

NEW PRODUCTS

2½ in. diameter aluminum housing—and this can include radio-interference filtering as well as a high-pulse-rate intercam reduction.

Motors that can be supplied are 50-, 60-, or 400-cps ac as well as standard or governed dc motors. Hence a wide range of basic speeds are available, plus intercam reductions up to 960:1. A. W. *Haydon, Waterbury, Conn.*

Circle No. 26 on reply card



PRECISION POT resolves sharply but weighs little.

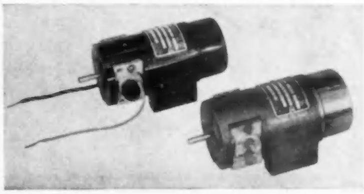
Here is a functional ten-turn miniature potentiometer, complete with servo or bushing mountings and ball bearings, which is about the size of a half-chewed Tootsie Roll and weighs only 1.1 oz. It contains an 18 in. mandrel-wound resistance element and is supplied in linear and non-linear versions.

Characteristics

Resistance Range....25-100,000 ohms
Resolution....as fine as 0.01 per cent
Linearity Tolerance..to 0.1 per cent
Power Rating..........2 w at 40 deg
Rotation..3,600 deg. starting from positive-zero

Helipot Corp., South Pasadena, Calif.

Circle No. 27 on reply card



TACH-GENERATORS smaller than your fist.

Member of this new series of dc motors and tachometer-generators are

less than 4 in. long by 2 in. in diameter, and each weighs less than 20 oz. Yet they have such high quality features as die-cast aluminum housing, cadmium plating, and great variety in brushes and commutators, which fit them for exacting and rugged jobs in airborne and earthbound servo systems.

Characteristics

Power Ratings.......1/30 to 1/100 hp
Voltage Required..........6 to 27.5 v
Speed.............3,000 to 9,000 rpm
Tach-Gen Output..from 0.46 to 2.4 vdc per 100 rpm to 9,000 rpm

Instrument Motors, P. O. Box 5, Stamford, Conn.

Circle No. 28 on reply card

INDUCTION RESOLVER passes U. S. Air Force standards.

Makers of this precision induction resolver declare that it is one of the very few of its type to pass the rigorous standards of the Air Force. Some conditions met:

Insulation Leak..100 meg at 500 v
Direct Current Leak..less than 5 microamp after 10 sec at 500 v
Transformation Ratio..0.9750 at 500 v, 500 cps input
Residual Null Voltage..less than 0.1 per cent of applied voltage
Ambient Temperature... −50 to +50 deg C
Humidity Tolerance..5 days at 100 per cent at 50 deg. C
Altitude......to 50,000 ft and down
Vibration.. 0.030 in total excursion for 30 min at 10-55 cps
Shock..series of five 10 g shocks in three planes

American Electronic Mfg. Co., Culver City, Calif.

Circle No. 29 on reply card

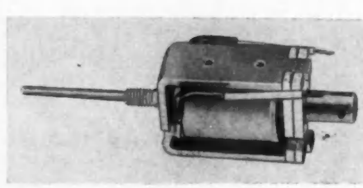
RELAYS, SWITCHES, SOLENOIDS

HYDRAULIC SWITCH nests in long plastic tube.

This switch suggests a fresh approach to problems of limit and positioning contact control in troublesome machine and conveyor belt control designs. It's a hydraulically operated self-contained electric switch running inside a ½-in. diameter flexible plastic tube, which is sensitive along its entire length. And, incidentally, this length can run up to 300 ft.

Palladium contacts with a capacity of one ampere form the actual switch. These are driven by transmitted pressure of the tube's hydraulic fluid and have an adjustable sensitivity from 1 to 8 oz. Hence any imposed pressure along the tube as it winds around a machine or over a conveyor can set off the signal. We are told that the tube itself can be bent 90 deg without impairing its action. Standard lengths are 6 and 12 ft. *Recora Co., 56 West 103rd St., Chicago.*

Circle No. 30 on reply card



BANTAM SOLENOIDS push and pull prodigiously.

This new line of miniature solenoids is unusual from several aspects. First, the series has 300 different members. Yet only 20 standard parts are used in assembling the whole line. We are told that this manufacturing economy is reflected in price. Also, the designers added a threaded receptacle to the in-end of the solenoid plunger. This makes it easily convertible from pull to push operation.

The solenoids range from about 1½ to 3 in. long and ½ in. in diameter. Power for coils runs from 5 to 70 w. In general, about 12 oz of thrust is available per 1,000 ampere-turns, with maximum work exerted at about .187 in. stroke. *Joseph Pollak Corp., 85 Freeport Street, Boston 22, Mass.*

Circle No. 31 on reply card

FREQUENCY RELAY trips at predetermined limit.

This black box will protect equipment from damage by too high or too low power frequencies. The critical frequency can be adjusted to within ½ per cent for any value between 50 and 500 cycles. When the value is exceeded the unit will open (or close) an appropriate relay. This action is independent of wide voltage variations. Two strips in a single unit can be set to operate at different levels of frequency and thus provide "high-low" protection. *Arga Div., Beckman Instruments Inc., South Pasadena, Calif.*

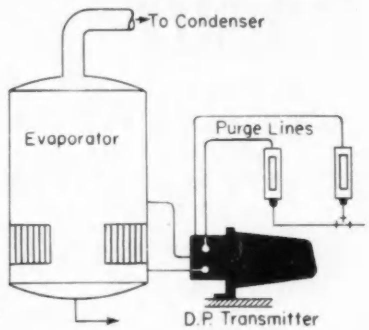
Circle No. 32 on reply card

PNEUMATIC RELAY turns two inputs into proportional output.

This new air-operated device accepts two input signals of from 3 to

GOOD FOR EVERY DAY AND SUNDAYS TOO!

AUTOMATIC PURGING OF SUSPENDED SOLIDS



Problem: To obtain uninterrupted liquid level measurement and control where solids in suspension could settle out, plugging lead lines and causing errors in measurement.

Solution: Dual taps provide for complete flushing of the 333RD body as well as the lead lines.

Result: Consistently high accuracy. Flushing of manometer and lead lines cuts maintenance to a minimum. Evaporator efficiency is kept at a uniformly high level.

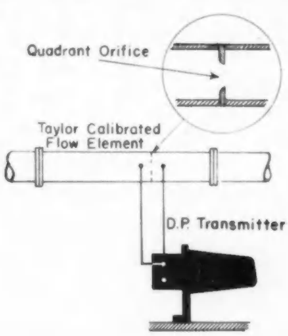
The Taylor TRANSAIRE* Differential Pressure Transmitter (333RD) is simple and economical, yet exceptionally adaptable!

IT'S inexpensive and easy to install—and to maintain. Changes in product or seasonal demand cause no problems, due to quick, simple range change feature. No seal pots—follows flows quickly because of low volumetric displacement. This pneumatic force-balance transmitter, designed to convert differential pressure into an equivalent 3 to 15 psi output, can be used to measure flow of liquid, steam or gas; liquid level or specific gravity. Pressure rating is 1500 psi, and it's available in any desired range from 20″ to 800″ of water.

Call your Taylor Field Engineer for details, or write for **Bulletin 98097.** Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada.

*Reg. U.S. Pat. Off.

HIGH ACCURACY WITH VARYING VISCOSITIES

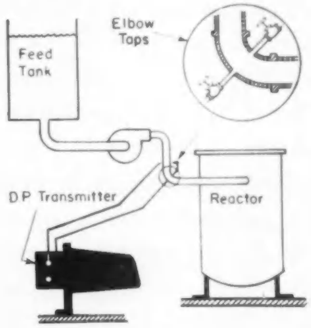


Problem: To get a high order of accuracy in measuring viscous fluids without special calibration curves and frequent changes in calibration due to troublesome variations in viscosity.

Solution: Its low volumetric displacement makes the 333RD transmitter ideally suited to capitalize on the improvements made possible by the recently developed European type quadrant orifice.

Result: Uninterrupted, accurate performance under difficult and variable viscosity conditions.

REVERSING FLOWS AND VARYING VISCOSITY



Problem: Flow control when there are changes in direction of flow and restrictions in the line are not desirable.

Solution: The use of the 333RD transmitter with Elbow Taps, as primary elements. Since there's a tendency to cavitation at the inside tap, the low volumetric displacement of the 333RD makes it particularly suitable.

Result: Accurate measurement, and consequently control, under very difficult conditions.

Taylor Instruments **MEAN ACCURACY FIRST**

Next Steps in Atomic Progress... A Challenge to American Industry

The purpose of this editorial is to throw light on the significance for American industry of recent changes in the statutes that control the development of atomic energy.

The need for clear light on the meaning of this new legislation is made more urgent by the political confusion and distortion that marked its course through Congress. The politically inspired charges of "giveaway" that delayed its passage — charges that were almost totally unrelated to the legislation itself — helped to obscure the vital importance of the step finally taken by Congress.

In sober, post-Congressional fact, the principal significance of the new atomic legislation is that it extends to private enterprise responsibility for the development of peaceful uses of atomic energy, whereas heretofore this responsibility has rested in a tight government monopoly. **And this extension is made on terms that emphasize the responsibility far more than they open any opportunity for economic gain in fulfilling it.** The revised Atomic Energy Act provides that:

1. Industry may now own and operate its own nuclear reactors, under license from the Atomic Energy Commission. And it may build and sell nuclear reactors for export.

2. Industry may use — but not own — nuclear materials at the discretion of the Atomic Energy Commission.

3. The Atomic Energy Commission will make available to industry scientific knowledge that may be useful in developing peaceful applications of nuclear energy.

4. For the first time, industry will have the right to patent inventions in the field of non-military nuclear energy. However, "basic" discoveries must be made available to all companies in the field for a period of five years, after which they, too, will revert to normal patent status.

Two Kinds of Know-How

These provisions, despite the imposed limitations, represent the first positive step toward development of nuclear energy for peaceful applications in the United States. Potentially useful knowledge, previously locked in the minds of government scientists, will now be available to all those who are willing and able to put it to work for the good of mankind.

The advantages to be gained from enlisting the talents of American industry in the development of peaceful atomic applications are imposing. As *The* (London) *Economist*, Europe's leading economic journal, recently remarked, "The atomic scientists are in a position to surmise how atomic energy can be applied... but they lack the specialized knowledge of engineering design and operating technique just as industry itself lacks atomic knowledge." Now the engineers of private industry need no longer lack the atomic knowledge, and there is granted to them at least a restricted freedom to apply it to the solution of their engineering and operating problems.

But the new opportunity for private industry to find constructive uses for the science of nucleonics carries with it a grave responsibility. These uses must be so developed that they will benefit the people of all the free nations. It is essential that the United States, which pioneered in developing lethal uses for atomic fission, demonstrate to the world our paramount interest in its peaceful application. It would be a moral set-back to the free world almost beyond calculation if the Communists should be able to offer to the poorer nations of the world the benefit of low cost atomic power—provided by Communist technicians—while we concentrate primarily on building our stockpile of atomic and hydrogen bombs.

Race For a Peaceful Victory

Most of the experts are agreed that it may be many years—perhaps ten, fifteen or more—before the cost of electricity from atomic fission can be reduced to a level that will make it competitive with conventionally produced power in most regions of the United States. But most of the world is not nearly so fortunate as we are in power resources. Electricity, even at a cost far higher than the average that prevails in the United States, would be a blessing in many countries, and the nation that provides the technology to bring it into being will score a great moral victory.

The useful potential of nuclear energy is not restricted to the generation of electric power—although twenty years from now this use will be highly important to the power industry of the United States. Even with the limited research that has been done in this field thus far, the use of radioisotopes—the radioactive products of atomic reactors—is saving American industry an estimated $100 million a year. Commissioner Campbell of the AEC, who made this estimate, believes that these savings may well reach $1 billion a year within ten years. Radioisotopes are already at work in industries ranging all the way from paper manufacturing, where they measure paper thickness, to pipeline transportation, where they mark the dividing lines between shipments of different products (at an estimated saving of $500,000 a year). Medical applications of these same radioisotopes hold promise of longer and more comfortable lives for those who are stricken by cancer and other diseases.

Above All a Challenge

The new Atomic Energy Act is a crucial stride toward the day when all these benefits—and undoubtedly others not yet revealed by research—will be realized. But it is a step that is essentially permissive. It still leaves it to private industry for the most part to decide what is to be done and how soon.

The new act is thus, above all, a challenge. It confers on private industry the responsibility to assume a leading role in the development of peaceful uses for nuclear energy, a step long urged by NUCLEONICS, a McGraw-Hill magazine devoted to atomic energy. To achieve a success in this task that will measure up to the requirement of the national interest, this development must command all the resources and ingenuity that private enterprise can apply—and do so without promise of glittering prizes surely to be won. **But now that the responsibility has been defined and the challenge offered, American industry will, we believe, measure up to its grave and mighty import.**

This message is one of a series prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments that are of particular concern to the business and professional community served by our industrial and technical publications.

Permission is freely extended to newspapers, groups or individuals to quote or reprint all or parts of the text.

Donald C McGraw

PRESIDENT

McGRAW-HILL PUBLISHING COMPANY, INC.

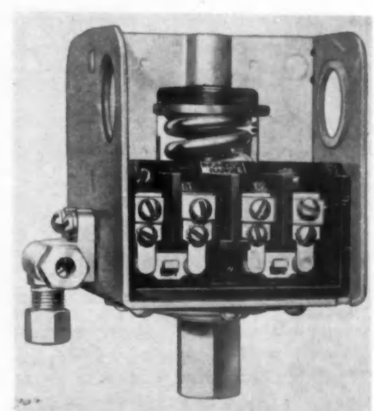
NEW PRODUCTS

15 psi—a primary and also secondary. The output pressure is proportional to the primary input. The degree of proportionality, or ratio, is determined by the magnitude of the secondary input pressure.

This type of ratio-signalling device has a function in process work where the relationship between two variables often has to be measured and controlled. For example, a reagent often has to be added to the main flow in some fixed ratio.

Maximum range of ratios in this device is 0 to 2.0, with limit stops beyond this on the output pressure. Adjustments are available for ratio-span setting, suppression for all pressures, and pulsation dampening on input and output. It has a high-capacity, non-bleed pilot valve to handle large loads without auxiliary boosters. *Minneapolis-Honeywell Regulator Co., Industrial Division, Wayne & Roberts Ave., Philadelphia 44, Penna.*

Circle No. 33 on reply card



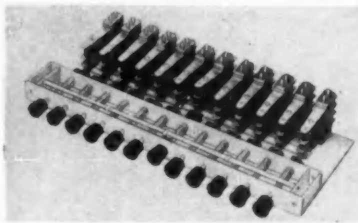
PRESSURE SWITCH ruggedly made for industrial jobs.

One of the features in this new line of pressure switches is its nylon-reinforced neoprene contact diaphragm. This, we are told, is almost indestructible and can be thin enough to be very sensitive. Other excellent points: all bearing surfaces are stainless steel; silver-alloy contacts; pressure-type terminal connectors.

These switches are made in batches to user's range and differential specifications. There are however, simple screw driver and small wrench ad-

justments for these settings on the job. Wide use for this new line is forseen in heavy duty pump and compressor applications where power rating is over 1 hp. *Cutler-Hammer, Inc., 312 N. 12th St., Milwaukee, Wis.*

Circle No. 34 on reply card

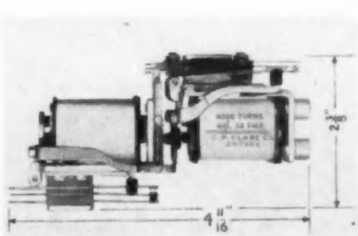


PUSH-BUTTON SWITCHES unitized for better service

The compact bank of push button switches shown is a newly designed version of the first heavy-duty unit of this type to be offered. Major improvements are a utilization of the switch into an integral group of from two to a maximum of twelve positions. This has improved ruggedness and reduced maintenance and behind-panel space. Further, the new switch elements themselves are more compact and sturdy because of fewer and stronger plungers and latch bars.

Types available: accumulative lock; no two interlock; lock release; and non-lock. Ratings and mounting dimensions are the same as the old standard line. *General Control Co., Boston 34, Mass.*

Circle No. 35 on reply card



ELECTROMECHANICAL latching relay has long life

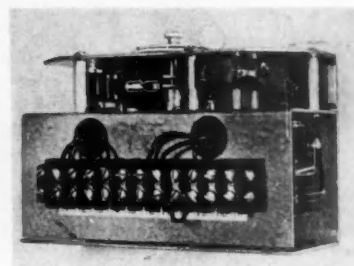
This relay is being widely used in high speed business machines. It has held up at well over 15,000,000 opera-

tions whereas other designs normally fail in after a few thousand repeats.

The picture shows how it is built. Two standard ac relays are aligned one above the other on a common mounting bracket and have interlocking armatures. This design permits a variety of functions:

- ▶ Interlocking relay pair on either ac or dc or combination
- ▶ Overload relay, remotely reset
- ▶ Operate contacts over one load and release them over another
- ▶ Hold contacts indefinitely without drawing power. *C. P. Clare & Co., Chicago, Ill.*

Circle No. 36 on reply card



DUAL TIMER nips false pumping in fluid distribution.

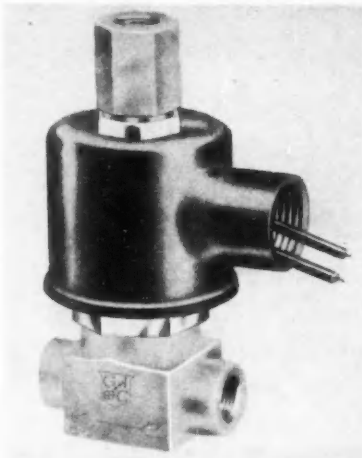
This motor-driven timer was especially designed for pumping in and pumping out situations in industrial and municipal fluid handling systems. It has two separate and independent timing circuits. One of these can be established for a constant period for fixed tank level in a system. The other can be tied into the pilot circuit of the pump control. When a surge condition occurs one component timer is actuated and takes over for a fixed period before pump shut-down. This prevents false starts and stops. The same general system protects against backspin in pumping systems.

The timer is about the size of a cigar box. It weighs about 4 lb and operates on 115 vac plus or minus 10 per cent or on 230 vac. *Automatic Control Co., 995 University Ave., St. Paul, Minn.*

Circle No. 37 on reply card

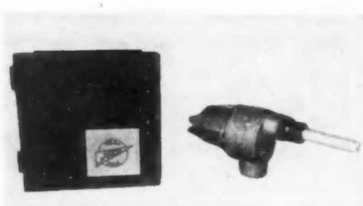
MIDGET SOLENOID powers this three-way valve.

Compact solenoid size plus its three-way axial outlet construction suggest



that this new valve will be useful as a component in machine control-system design. It can be furnished for normally closed or normally open three-way operation as well as for straight directional flow control. Body comes in either brass or stainless steel. *General Controls Co., Glendale, Calif.*

Circle No. 38 on reply card



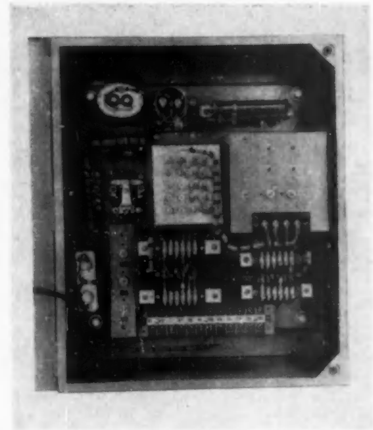
LEVEL PROBE teflonized to obviate shorting.

Teflon blankets this capacitance-type liquid-level probe to keep it from shorting out to ground. The probe is set in a compact and sturdy housing which can be directly tapped into a vessel or downmounted from above. It hooks up to an electronic bridge circuit, which can be as far as 500 feet away with simple cable connections.

The maker claims this new probe system will give an electric contact in almost any material. It is available in several models for temperatures from minus 30 to 1000 deg F and for pressures up to 1500 psig. *Jarco Services Inc., 725 South Erie, Tulsa, Okla.*

Circle No. 39 on reply card

NEW PRODUCTS



MAGNETIC AMPLIFIER applies in exciter control.

Makers of this magnetic-amplifier voltage regulator claim it is the first of its type developed for exciter control. It has already been used on several 5 to 150 kw generators, with prime movers including diesel engines, synchronous or dc motors, and steam turbines.

Characteristics

Response ....1/400 sec
Rated Frequency......380 to 420 cps
Error..less than 1 per cent under extreme field voltage swings; less than $\frac{1}{4}$ per cent normally
Range..operates with generator having voltage ratings of 120, 208, 220, 440, 480 on single or three phase.

Regulator Equipment Corp., Paterson, New Jersey

Circle No. 40 on reply card

FEEDBACK FANCY

Needed: A feedback system that would wake the slumberer as soon as he is well rested.

Suggested: An electroencephalographic pickup that would detect revivification patterns in brain waves and ring a bell. The alarm clock certainly can't tell when a man has had as much sleep as he needs.

Bulletins & Catalogs

ISSUED SINCE AUGUST 15

Here's how to get important literature that belongs in your technical library. Selected by the editors of CONTROL ENGINEERING, it is yours at no cost.

Circle here →

The numbers you

select here ↓

Postage Will be Paid by McGraw-Hill Pub. Co.

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 64, (Sec. 34.9, P. L. & R.) New York, N. Y.

Reader Service Department
CONTROL ENGINEERING
330 West 42nd Street
New York 36, N. Y.

Not good if mailed after January 1, 1955

Send me manufacturers' BULLETINS and CATALOGUES and further information about NEW PRODUCTS, as indicated by the numbers I have circled.

1	8	15	22	29	36	43	50	57	64	71	78	85	92
2	9	16	23	30	37	44	51	58	65	72	79	86	93
3	10	17	24	31	38	45	52	59	66	73	80	87	94
4	11	18	25	32	39	46	53	60	67	74	81	88	95
5	12	19	26	33	40	47	54	61	68	75	82	89	96
6	13	20	27	34	41	48	55	62	69	76	83	90	97
7	14	21	28	35	42	49	56	63	70	77	84	91	98

Name......................Title......................................

Company..

Address..11/54

CONTROL ENGINEERING—A McGraw-Hill Publication

(51) CONTROLLED - VOLUME PUMPS. Milton Roy Co., Bulletin 1253, 20 pp. Describes and illustrates how controlled volume pumps can be used as flow controllers, ratio controllers, and final control elements. Engineering data section tells how fluid characteristics and piping affect the operation of these pumps.

(52) PRECISION COMMUTATOR MOTORS. Electric Indicator Co., Inc., Catalog EL-2A, 22 pp. Complete engineering data on over 225 fractional- and sub-fractional-hp motors. Types include PM dc, dc shunt, separately excited shunt, split-field shunt, series, split field, universal, split-field universal, and governor motors.

(53) MANUFACTURING CONTROL. International Business Machine Corp., Brochure, 28 pp. Describes methods for administering the functions of production management using punched card techniques.

(54) ADJUSTABLE-SPEED MOTORS AND CONTROLS. Reliance Electric and Engineering Co., Booklet, 12 pp. Tells about a philosophy of combining applied engineering, creative thinking and electric motor drives to the automatic control of single machines and continuous processes.

(55) STEAM AND GAS FLOWMETER. King Engineering Corp., Catalog 5001, 4 pp. Covers design and application of nozzle-type flowmeter that operates by establishing critical-flow conditions in the nozzle. Engineering specifications are given for a line of these meters.

(56) PLASTIC INSULATED WIRE. Tensolite Insulated Wire Co., Inc., Catalog, 16 pp. Gives specifications of a line of miniature and sub-miniature insulated stranded wires and tinsels. Includes wide variety of wire and cable construction.

(57) MULTI - TUBE PNEUMATIC CONDUIT. Crescent Insulated Wire & Cable Co., Bulletin, 4 pp. Describes a line of armored-steel conduit containing from 2 to 19 pneumatic tubes of copper, aluminum, polyethylene, and other plastics.

(58) PRESSURE - MEASURING ELEMENTS. The Foxboro Co., Bulletin 6-10, 24 pp. Engineering specifications and application data on a line of pressure instruments designed for direct measurement, remote transmission, and automatic control. Includes useful chart: "How to Select the Measuring Element".

(59) MINIATURE PAPER CAPACITORS. The Gudeman Co., Catalog X-100, 19 pp. Complete information on a line of miniature, hermetically-sealed, high-temperature tubular paper capacitors. Included are dimensional drawings, engineering data, and tables of voltages, capacitance values, and tolerances.

(60) DATA-PROCESSING SYSTEMS. Electrodata Corp., Bulletin EDC-3200, 19 pp. Discusses the application of a line of data-handling equipment to engineering computation, production planning and control, process monitoring and control, scientific research, distribution, and management planning and accounting.

(61) SILICON TRANSISTORS. Texas Instruments Inc., Bulletin DL-S 426, 2 pp. Describes a family of silicon transistors and silicon junction diodes. Complete electrical and mechanical characteristics are given.

(62) PROGRAM TIMER. Taylor Instrument Cos., Bulletin 98350, 8 pp. Describes and tells how to use a timed-program controller for the timing and coordination of batch processes. Actuating components can be either electrical or pneumatic.

(63) DELAY LINES. Richard D. Brew and Co., Inc., Catalog 54, 12 pp. Includes illustrations, descriptions, and technical data covering lumped-constant, distributed-constant, and ultrasonic delay lines. A procedure for testing delay lines is also described.

(64) FLEXIBLE SHAFTING. Stow Manufacturing Co., Bulletin 525, 12 pp. Information on a line of flexible shafting plus procedure for selecting shafting for a specific application. Company also offers flexible-shafting-torque calculator.

(65) DATA-DISPLAY INDICATORS. Union Switch and Signal, Bulletin 1001, 4 pp. Describes indicators for data display and data transfer. Each indicator can dis-

Not good if mailed after January 1, 1955

Send me manufacturers' BULLETINS and CATALOGUES and further information about NEW PRODUCTS, as indicated by the numbers I have circled.

1	8	15	22	29	36	43	50	57	64	71	78	85	92
2	9	16	23	30	37	44	51	58	65	72	79	86	93
3	10	17	24	31	38	45	52	59	66	73	80	87	94
4	11	18	25	32	39	46	53	60	67	74	81	88	95
5	12	19	26	33	40	47	54	61	68	75	82	89	96
6	13	20	27	34	41	48	55	62	69	76	83	90	97
7	14	21	28	35	42	49	56	63	70	77	84	91	98

Name........................Title..

Company...

Address...11/54

CONTROL ENGINEERING—A McGraw-Hill Publication

Postage Will be Paid by McGraw-Hill Pub. Co.

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 64, (Sec. 34.9, P. L. & R.) New York, N. Y.

Reader Service Department
CONTROL ENGINEERING
330 West 42nd Street
New York 36, N. Y.

play 64 different characters in response to codes that emanate from central control equipment. Devices are based on positioning system that uses a six-place binary code on six wires.

(66) PRECISION GEARS. Feedback Controls, Inc., Brochure, 8 pp. Covers a line of gear heads, gear trains, and speed reducers designed for precision automatic control systems and analog computers.

(67) ELECTRICAL CERAMICS. General Ceramics Corp., Brochure, 4 pp. Includes useful table listing electrical and mechanical properties and recommended general applications for various types of ceramics. Typical materials include steatite, forsterite, porcelain, filter elements, and porous diaphragms.

(68) TEST STANDS. Industrial Engineering Corp., Bulletin 541, 6 pp. Features details of availability of custom-built test stands made up of standardized units. Equipment will test hydraulic, pneumatic, or electrical circuits. All stands have graphic panel of test system.

(69) AC RATE GENERATORS. Ford Instrument Co., Bulletin, 4 pp. Describes a line of stable, linear ac rate generators with high output, available in 60 and 400 cps models. Information on construction, applications and performance characteristics is included.

(70) VIBRATION-SENSITIVE ELEMENT. The Beta Corp., Bulletin 500-1, 4 pp. Device trips internal relay when vibration exceeds preselected amount. Mechanical, electrical, and frequency-response data are given.

(71) INDUSTRIAL INSTRUMENTS. The Bristol Co., Bulletin DMO35, 8 pp. Briefly scans a complete line of automatic controlling, recording, and telemetering instruments. Gives sufficient information so that more specific bulletins can be ordered that cover instruments of particular interest.

(72) PRECISION - SERVO SYSTEM. Richardson Scale Co., Technical Reference 54B, 4 pp. Describes and discusses applications of a packaged 60 cps servo system. Components included are a synchro transmitter, control transformer, servo amplifier and servomotor.

(73) PACKAGED BOILER CONTROLS. The Hays Corp., Publication 53-1088-239, 4 pp. Information on a fully automatic, all-electric metering-packaged control for shop-assembled boilers. Schematic shows typical control system for a combination oil-and-gas-fired boiler.

(74) STRAIN GAGES. Baldwin-Lima-Hamilton Corp., Bulletin 4300, 20 pp. Roundup giving a general description of several types of strain gage devices together with their varied applications. Many illustrations and useful circuit diagrams.

(75) CONTROL VALVES. Ledeen Manufacturing Co., Bulletin 1010, 16 pp. Describes a line of standard 4-way hand-, foot-, power-, and solenoid-operated valves. Also includes pilot valves. Complete mechanical, electrical, and performance data are given.

(76) SPEED REDUCERS. Cone-Drive Gears, Div. Michigan Tool Co., Bulletin CD-323, 8 pp. Details of a line of shaft-mounting speed reducers available in models to handle loads from fractional to 9 hp, motorized or standard.

(77) CONSTANT-VOLTAGE TRANSFORMERS. Sola Electric Co., Booklet, 20 pp. Written for electrical engineers and others interested in the underlying electromagnetic relations and design principles of one type of constant-voltage transformer.

(78) VISCOSITY CONTROL. Norcross Corp., Bulletin V-1000E. Describes a viscometer that automatically measures and records viscosity. Can also be used for automatic control. Performance and application data are included.

(79) SERVO ANALZER. Minneapolis-Honeywell Regulator Co., Bulletin 1170, 16 pp. Describes and tells how to use a servo analyzer that can automatically measure and plot phase and attenuation characteristics by the use of mechanical, electrical or pneumatic sine waves.

(80) DEW-POINT HYGROMETER. Burton Manufacturing Co., Bulletin 900-1, 4 pp. Describes an electronic hygrometer that uses the light reflected from a dew-filmed mirror to measure dew point. The mirror is maintained at dew-point temperature and the output of a thermocouple attached to the mirror can be used to record or control dew point.

(81) MOTOR-DRIVES. U. S. Electrical Motors Inc., Booklet 1878. Multi-color booklet shows 20 types of motors and variable speed drives. Includes cut-open views of many of the units .

(82) HIGH-VOLTAGE TESTERS. Beta Electric Corp., Catalog 5, 8 pp. Describes a line of high-voltage power supplies and high-potential testers. Complete electrical characteristics are given and typical applications are suggested.

(83) ELECTRONIC INSTRUMENTS. Hewlett-Packard Co., Short Form Catalog, 8 pp. Brief but complete information on an extensive line of electronic instruments. Typical items are amplifiers, electronic counters, low-pass filters, power supplies, and waveform analyzers.

(84) ELECTRICAL INSULATION. Mycalex Corporation of America, Handbook, 24 pp. Covers properties of various types of glass-bonded mica. Also describes engineering materials and components that are formed from glass-bonded mica.

WHAT'S AHEAD: MEETINGS

OCTOBER

American Society for Metals, 36th National Metal Congress and Exposition, Palmer House and International Amphitheater, Chicago, Ill. Oct. 29-Nov. 5

NOVEMBER

Institute of Radio Engineers, Conference on Airborne and Navigational Electronics, Sheraton-Belvedere Hotel, Baltimore, Md. Nov. 4-5

National Electrical Manufacturers Association, Annual Meeting, Haddon Hall Hotel, Atlantic City, N. J. Nov. 8-11

American Petroleum Institute, 34th Annual Meeting, Conrad Hilton Hotel and Palmer House, Chicago, Ill. Nov. 8-11

American Institute of Electrical Engineers, Institute of Radio Engineers, and Instrument Society of America, Conference on Electrical Techniques in Biology and Medicine, Morrison Hotel, Chicago, Ill. Nov. 10-11

Institute of Radio Engineers, Quality Control Symposium, Statler Hotel, New York, N. Y. Nov. 12-13

American Standards Association (Fifth National Conference on Standards and Thirty-sixth Annual Meeting), Hotel Roosevelt, New York, N. Y. Nov. 15-17

The American Society of Mechanical Engineers, Annual Meeting, Statler Hotel New York, N. Y. Nov. 28-Dec. 3

DECEMBER

National Exposition of Power and Mechanical Engineering, Commercial Museum, Philadelphia, Pa. Dec. 2-7

Eastern Computer Conference, Bellevue-Stratford Hotel, Philadelphia, Pa. Dec. 12-15

JANUARY

Society of Automotive Engineers, (Golden Anniversary Annual Meeting), The Sheraton-Cadillac Hotel and Hotel Statler, Detroit, Mich. Jan. 10-14

American Institute of Electrical Engineers and Institute of Radio Engineers (devoted to high frequency measurements), Hotel Statler, Washington, D. C. Jan. 17-19

American Institute of Electrical Engineers (winter general meeting), Hotel Statler, New York, N. Y. Jan. 31-Feb. 4

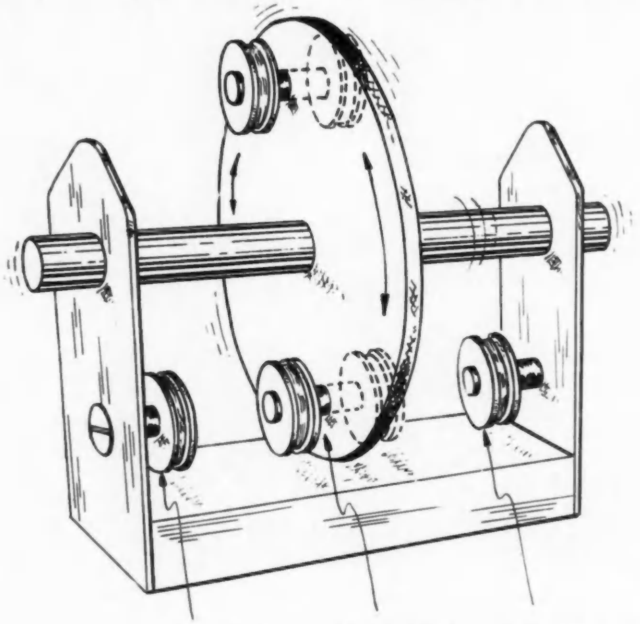
WHAT'S NEW: ABSTRACTS

Telemeters Turbine Temp

From "Turbine Blade-Temperature Telemeter." Summary Technical Report, National Bureau of Standards, September 1954

A complete instrumentation system for remote indication of gas turbine blade temperatures has recently been designed for the Navy Bureau of Ships. The system includes special high-temperature resistance thermometers that withstand large centrifugal forces, an inductive commutator that transmits signal information from the high-speed rotor to external stationary equipment, and electronic circuitry that interprets the telemetered signals as temperature measurements.

Tests on turbines under actual operating conditions indicate that temperature measurements may be made with the instrumentation system more accurately than plus or minus 25 deg F at temperatures up to at least 1,400 deg F, where more conventional methods used on lower-speed machinery are not applicable.



Essentially the inductive commutator consists of several pairs of input and output coils on the rotating shaft, with one stationary set of energizing and information-receiving coils mounted on the turbine frame. Rotation of the shaft brings each coil into and out of coupling with the stationary coils. Each channel or set of rotating coils is sampled periodically with rotation. Thus signal information is sequential.

One stationary coil is excited with current at a low radio frequency; the other stationary coil serves as the source of output voltage. On the rotating structure, the coil pairs are electrically connected together and shunted by the variable-resistance thermometer element. One of the rotating pair couples electromagnetically with the exciting stationary coil, the other with the output coil. The result is that the amount of transferred energy is governed by the resistance of the thermometer element when its particular rotating-coil is coupled to the stationary coils.

In order to make the output-voltage magnitude independent of the strength of excitation of the input coil, one of the channels is used for calibration, and a fixed, known resistance is substituted for one of the temperature-sensitive elements. Thus the ratio of the output of any of the signal channels to that of the calibration channel is the true measure of the resistance of the sensing element.

Because they must withstand high centrifugal forces, possibly as high as 100,000 g's, conventional construction techniques for resistance thermometers do not apply. The elements are designed to minimize the stress on the temperature-sensing winding.

The resistance thermometer is contained in a thin-walled tube of inconel, approximately .040 in. in diameter—about the size of an extra-thin automatic pencil lead. The temperature-sensing element consists of a 24-turn coil of .001 in.-diameter platinum or rhodium wire in a helix about .024 in. in diameter and ⅛ in. long. Thus the effective temperature-sensing area is small. Leads to the winding are heavier, low-resistance, low-temperature-coefficient wire.

The thermometer is inserted into a radial hole drilled in the turbine blade. Centrifugal force acting on the structure assures physical "bottoming" of the thermometer against the end of the hole in the blade, providing both mechanical support and thermal contact. The element is imbedded in a ceramic cement to prevent relative motion between the delicate winding and the point of attachment of the external leads.

What Cost Performance?

From "Cost vs. Performance in Process Control Systems" by P. S. Buckley, E. I. du Pont de Nemours & Co., Orange, Texas. Paper presented at the First International Instrument Congress and Exposition, Philadelphia, Pa., September 1954. ISA Paper No. 54-20-3

Frequency response techniques have made possible quantitative design and evaluation of process control systems. Process-control studies can now be made which quantitatively relate cost and performance.

The classical method of installing a pneumatic control system is to mount the controller and manual-automatic station on the main control board. A few years ago people who were interested in getting faster performance out of flow-control systems began to install the controllers close to the valve and to the flow transmitter in order to get snappier action. This cut down pneumatic transmission lags. There have also been efforts to speed up both board-mounted and field-mounted systems by boosters. Isolating relays cut out transmission losses between field-mounted systems and the board.

Four basic systems are compared:

Case 1: Controller mounted on central control board, 250 ft from valve and flow transmitter. Valve equipped with positioner only.

Case 2: Controller field-mounted 10 ft from transmitter. Valve is 10

ft from cut-off relay. Valve equipped with positioner only.

Case 3: Controller is field-mounted as above. Valve equipped with positioner plus booster.

Case 4: Same as Case 3, but with isolating relay in transmitter output line to indicator and recorder on main control board.

The comparative performance of these four systems is defined in terms of the frequency at which the regulation is .5 per cent flow per per cent pressure-drop disturbance, and the frequency at which regulation is .1 per cent flow per per cent disturbance.

For Case 1, the regulation is .5 at 1.8 cps and .1 at .3 cps.

For Case 2, the regulation is .5 at 4.8 cps and .1 at .66 cps. Better than Case 1 by 120-170 per cent.

For Case 3, the regulation is .5 at 8.4 cps and .1 at 1.2 cps. Better than Case 1 by 300-370 per cent, and better than Case 2 by 75-82 per cent.

For Case 4, the regulation is .5 at 30 cps and .1 at 3.5 cps. Better than Case 1 by 1,100-1,570 per cent, and better than Case 3 by 190-260 per cent.

For Case 1, a typical installed cost might be $3,300.

Case 2 costs about $700 more, because of extra tubing and field installation. Increased cost over Case 1, 21 per cent.

Case 3 has two more booster relays. Installed, another $100. Increased cost over Case 1, 24 per cent; over Case 2, 2.5 per cent.

Case 4 has still another booster relay. Cost, another $50. Increased cost over Case 1, 26 per cent; over Case 3, 1.2 per cent.

Now compare incremental cost with incremental performance. In comparison with Case 1, we get the following results:

1) Case 2 is better by 120-170 per cent for a cost increase of 21 per cent; 2) Case 3 is better by 300-370 per cent for a cost increase of 24 per cent; 5) Case 4 is better by 1,100-1,570 per cent for a cost increase of only 26 per cent.

In many plants the need for fast, precise flow control has already led to the Case 2 arrangement of instruments in place of Case 1. If we use Case 2 as the base, the results may be expressed as follows: 1) Case 3 is better by 75-82 per cent for a cost increase of 2.5 per cent; 2) Case 4 is better by 430-525 per cent for only 3.75 per cent more.

A Biologist Views Control

From "Control in Biology" by H. Mittelstaedt, Max Planck Institute, Wilhelmshaven, Germany. An article in German, published in "Regelungstechnik," Munich. Volume 2 (1954), No. 8, Pages 177-181.

Feedback control systems—and this has been said repeatedly in recent years—display phenomena previously found only in connection with living beings. Engineers and mathematicians have successfully condensed the laws of control and regulation to a mathematical theory of general applicability. This theory allows them to calculate, predict, and modify the behavior of technical control systems.

HOW A FISH BALANCES

For the biologist the question arises whether and to what extent this theory of control may be applied within the realm of living creatures. For a comparison, the author describes a liquid-level control system and the equilibrium or balance that a fish exhibits when swimming at constant speed. From a front view, the fish is balanced vertically. If the fish is disturbed from its upright position by an external force, it will return very rapidly to this position. A plot of position against time gives the familiar picture of an over-damped oscillation.

In the liquid level control system, if the water level suddenly drops because water has been removed, the inlet valve opens to fill the container again. A time-response record will show the same picture as in the case of the fish. At this point, the comparison of the two different systems is a mere analogy.

If we shut off the water in front of the control valve, the valve opening can be observed as a function of water level. This is found to be linear. That is, $y = Kx$; y is the valve position and x is the water level. The important fact is this: the equation is reversible, but the relation between the valve opening and the water level is not. Apparently this system has the characteristic of transmitting changes of position one way only. It acts as a mechanism free from retroeffects—as a rectified link of transmission.

By taking this fact into consideration, we gain a decisive insight into the application of control theory to biological problems. It is possible to derive the basic concept of the theory, which is the concept of the rectified link, from the mere observation of the behavior of two magnitudes of condition, without knowing anything about participating forces.

A tiny organ in the inner ear on each side of the fish transmits a continuous series of impulses to the brain. If the fish is inclined from its normal position, the frequency of the impulses will rise on one side and sink on the other. The decisive point is that this relation, too, is not reversible. Electrical stimulation of the nerves may have an effect on the position of the fish via the central nerve-system and the muscular system of the fins, but not via the nerves and organs of sense. Just as in the technical case of the water-level control, changes of position in the biological process will cause action in one direction only.

These two systems, one technical and one biological, will return after each disturbance to the only position of equilibrium which is possible to them. The fish will return to the upright position. The liquid will return to its normal level. These systems are not at all alike, either in their exterior appearance, or by the nature of their "building materials," or in the physical mechanisms on which the operation of their elements depends. And yet, they behave exactly alike in equivalent situations.

In a system with elemental parts that are so different, there must necessarily be small groupings of parts that have the same transfer function, if the entire systems are to behave alike. To relate the technical theory to bi-

FEEDBACK FACT

Posed: An instrument to convey mental images to the blind.

Solved: Franz Ollendorf at Israel Institute of Technology, Haifa, is working out electroencephalographic methods that implant "sight" patterns in the brains of the blind.

ology, the author prefers to call these groupings of elements "control bodies." The systems behave in the same way because they are made up of the same control bodies—and also because the form of coupling of the bodies is the same in both of them.

Some of the advantages to be gained by the application of control theory to physiology are 1) new hypotheses, 2) new methods, and 3) new manner of presentation.

For example, in the case of the fish, a new hypothesis arises when we consider the result of control theory. How can the fish change its position by itself? There are only two possible solutions. Either the regulation process is interrupted for the duration of the self-motion, or the central-nervous command, which controls the self-motion, is superior to the continuing equilibrium process. In the shop-talk of control, the command acts as a leading signal which modifies the action. This second hypothesis was not even considered until recently.

HOW CONTROL THEORY HELPS

Control theory also provides new methods of examination for the physiologist. In the case of the fish's equilibrium control, the frequency response may be derived from the transfer functions of the two control bodies. It is necessary to calculate the frequency response of only one of the two control bodies. The second one is known if the overall frequency response is known. Hence, results the possibility of quantitatively clearing up the nature of parts of the system that are not accessible to experiments.

As for the new manner of presentation, we have seen that it is possible to describe the operation of the equilibruim mechanism of a fish without knowing the fine structure of the nervous system and its attached organs. No hypotheses were established about the participating, physical-phsiological mechanisms. It was not necessary to know the significance, the purpose, or the task of the examined system.

One of the classical biological methods makes use of models. Models are tangible and objective, but unfortunately do not exactly fit reality. In our example, the behavior of the fish can be represented by the model of the liquid-level control. The sense organs, however, consist of two consecutive control bodies and neither find any analogy in the water-level control. The value of control theory lies in the fact that even if the block diagram is amplified by the meshes and return-leads, or if it is enlarged by adding auxiliary and leading circuits, the basic structure, the control loop, remains distinct.

Steurn und Regeln

From "A German-English Dictionary of Automatic Control Terms" by D. W. Pessen, Brown Instruments Div., Presented at the Instruments and Regulators Division Conference, Philadelphia, Pa. Septemper, 1954. ASME Paper No. 54-IRD-4

Since the science of automatic control is relatively new, most of the terms associated with it have crystallized only during the last decade. It is therefore no wonder that existing German-English scientific dictionaries include virtually no automatic control terms. This has made it difficult for the English-speaking reader to follow the German literature on the subject. The purpose of this dictionary is to fill this gap.

This dictionary lists many technical terms of a general nature, used frequently in German articles on the subject. A list of standard German automatic control symbols and conventions is included in the appendix. The aim is not to supplant, but rather to supplement, existing German-English scientific dictionaries.

Electronics in Control

From "Why Electronic Process Control?" by D. M. Boyd, Universal Oil products. Paper presented at the First International Instrument Congress and Exposition, Philadelphia, Pa., September 1954. ISA Paper No. 54-9-2

Electronic control for industrial processes has been a popular subject in recent years. Most people associate electronics with very high speed. Presently available electronic controllers are actually slower, however, than a modern force-balanced controller mounted directly on the valve.

The reason for this is that although the measurement of the process variables, the transmission, and the controlling is done electrically, the final control element, the valve, is still positioned by compressed air. The biggest contribution of the electronics field to the field of automatic control has been the adoption of frequency-response techniques in process control. It is now possible to compare the relative merits of control systems on a quantitative basis.

To evaluate the relative performance of electronic controllers and pneumatic controllers, frequency response tests were made on two of each. When mounted directly on the valve, the pneumatic controller came out best.

The introduction of only 6 ft of ¼-in copper tubing brings the performance of the pneumatic controller down to that of the electronic controllers. If one element in the control system is slow the whole system is slow.

With the controller 100 ft from the valve, the electronic controller is far better. Addition of an amplifying relay or valve positioner will help the magnitude ratio in a pneumatic system, but rather serious phase-shift difficulties can arise. These can foster stability problems.

The electronic controllers, then, are not quite so fast as properly installed pneumatic controllers but are faster than the usual installation of pneumatic controllers.

If speed is the only consideration, industry is probably not ready to change to electronics. In cold weather, wet instrument air can leave the operators blind as far as conditions in the system are concerned. Electronic instruments would at least give a measurement under these conditions. It is unfortunate that they still require air to move a control valve.

An electric motor geared to the valve shaft is not a present solution. The average process control valve spends 90 per cent of its life in one position moving very slightly either

FEEDBACK FACT

Posed: A way to smash the world with a giant meteor.

Solved: Hayden Planetarium's new pushbutton console simulates this cataclysm with a blinding white flash projected on its 9,000-sq-ft dome.

"Darn good thing they have a good engineering school or I could never face the boys at work."

way from this point. A more practical solution may be an electrohydraulic approach. The output of the controller would be used to operate the pilot valve in the hydraulic line. Such a system can have extremely high performance. But responses faster than 1 cps are unnecessary for most process uses. Summing up the case for electronics:

▶ Electronic controllers are more reliable in cold climates.

▶ Electronic controllers do not need tubing racks. Electrical leads can be pulled through conduits in the regular pipe rack.

▶ Electronic controls are more flexible in complicated control problems. They will allow easier integration of the computer into the processing plant.

▶ Electronic controllers should be able to give better control. This does not mean faster control. Process lags are long and the dead-band in the controller is important.

▶ Electronic controls should have less noise. Derivative action in the controller can shorten process lag. Noise in the system can cause trouble, however. With the electronic controller, better filtering of undesirable noise may make possible more effective use of the derivative function.

Digital Data Handling

From "An Automatic Data Handling System For Process Plants" by J. F. Bishop and A. C. Knudsen, Beckman Instruments, Inc. and K. P. Lanneau and M. O. Gernaud, Standard Oil Co., La. Paper presented at the First International Instrument Congress and Exposition, Philadelphia, Pa., September 1954. ISA Paper No. 54-41-4

Only a few years ago lengths were generally gauged by rulers, weights by balances, and temperatures by glass thermometers. All of these, demanded continuous services of the eye and hand of a man, who translated the information to numbers on a log sheet, which could be used for calculations, correlations, and decisions.

Today analog measurements are made with primary elements that read out on recorders and indicators in the plant control room. Before data from recorders can be used in calculations, the recorded variable must be converted manually into digital form. Mechanization of chart reading overcomes some disadvantages of analog recording; but the data is no more accurate than the analog plot. Even where recording is used extensively, it is still common practice to maintain control room log sheets.

This paper describes a fully automatic system that converts raw data from the analog signal of the primary sensing elements to digital form without intermediate recording. It reports the data in terms of pounds, grams, inches, degrees Fahrenheit, Centigrade, or any other appropriate units. Data are presented in the plant control room in the usual tabular log sheet form on an electric typewriter, and at the same time any data may be automatically stored by a card or tape system. The necessity for manual logging is completely eliminated, and data is re-stored in a form that permits immediate calculations for accounting purposes or for process studies. Telemetering of data from the control room to other points is easy. The low cost and speed of data handling with this new system permits utilization of process information to an extent not possible heretofore.

The system incorporates:

▶ Ability to scan many primary sensing elements in a short time, and to measure the output of these elements in any abritrarily chosen scale.

▶ Accuracy of readout compatible with the accuracy of sensing elements.

▶ Data printed horizontally against vertical time.

▶ Automatic scanning of all channels at preselected time intervals.

▶ Compact mounting in a single, easily serviced desk console.

Read-out accuracy is plus or minus .1 per cent. Standard computing machines can be integrated directly into the system, yet means for intermediate study of plant data by the operator and engineer is provided.

Varying the voltage across the slide wire of a standard millivolt recorder, when the slide-wire shaft is connected directly to a shaft-position-to-digital-converter, will match the slope of the digital-millivolt curve of the slide wire to that of any of the transducers. The range of the slide wire voltage decided upon for the present unit is 5 to 50 mv. The desired full-scale slide-wire voltage is preset for each channel so that any change in the signal voltage from each primary sensing element, when matched against an equal voltage change from the slide wire, gives the correct digital change.

This data-reduction system is going into operation on a large-scale petroleum-processing pilot plant at Esso Standard Oil Co. in Baton Rouge, La.

How to be Logical

METHODS OF REASONING. *P. D. Scott, Ohio Bell Telephone Co., 8½ by 11 in., booklet, 16 pp. Published by Cleveland Engineering Society, 2136 E. 19th Street, Cleveland 15, Ohio. $1.00.*

This booklet accepts the fact that logic is desirable for the solution of problems. Starting from the basic definition of reasoning, the author proceeds through easily assimilated steps covering the concept of the sensed difficulty, techniques of establishing the problem, and how to state the approach and the method of arriving at sound solutions.

Among many interesting chapter headings are: Who Thinks?, What Thinking Is, What Meaning Means, What Is So, Cause and Effect, About Rules, There Is More Than One Answer, Can You Prove It?, and The Other Person.

Servomechanisms Primer

SERVOMECHANISMS. *John C. West, Lecturer in Electrical Engineering, University of Manchester. 5⅝ by 8¾ in., 238 pp. Published by English Universities Press Ltd., Saint Paul's House, Warwick Square, London, England. Distributed in the U. S. by The Macmillan Co., 60 Fifth Ave., N. Y. 11, N. Y. $5.00.*

This new book from England is a primer, concerned solely with electromagnetic servos. Mathematics is at the undergraduate level.

The subject is developed from simple examples, and new ideas are introduced by dealing with a particular case before proceeding to the more general principles. For this purpose, a single model is described and used as an example throughout the book. This tends to serve the same purpose as the actual demonstration of such a model in a course of lectures.

Some of the topics include: open- and closed-loop control, friction damping, rate feedback, integrating and differentiating circuits, frequency response plotting, stability, and error smoothing.

A chapter called Consideration of Stability from the Open-Loop Frequency Response Function discusses the polar and logarithmic forms of the response, Nyquist's Theory of Stability, phase-lead techniques, the concept of gain and phase margins, and conditionally stable systems.

Other chapters discuss speed control, integral control, dc amplifiers, rotary amplifiers, servomotors, some

graphical techniques for predicting stability from the open-loop frequency-response locus, the effects of saturation, and the treatment of nonlinearities.

The book does not mention the effects of noise, non-linear theory, treatment of backlash- on-off or sampled-data systems, or hydraulic and pneumatic elements.

Electronics in Los Angeles

REPORT ON THE ELECTRONICS INDUSTRY. *The Electronics Committee, Los Angeles Chamber of Commerce. $8\frac{1}{2}$ by 11 in., 44 pp. booklet. Published by Los Angeles Chamber of Commerce, 1151 South Broadway, Los Angeles 15, Calif.* $1.00.

This report is the result of the first project undertaken by the Electronics Committee. The Committee was formed by a group of industry leaders on March 1, 1954. This is the first survey ever published on the electronics industry for any major metropolitan area.

In the Los Angeles area, the electronics industry employs 60,900 people, with an estimated annual payroll of $231,000,000. There are 374 manufacturing firms, 161 firms doing research and development work, 19 engineering and design firms, and 22 in the service and testing business.

Dielectrics—Practice

DIELETRIC MATERIALS AND APPLICATIONS *Edited by Arthur R. von Hippel, Professor of Electrophysics, Massachusetts of Technology, $8\frac{5}{8}$ by $11\frac{1}{4}$ in., 438 pp. Published by John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. and The Technology Press of The Massachusetts Institute of Technology.* $17.50.

The material in the book is so arranged that it can be used as a comprehensive review of the whole subject or for reference on specific aspects. It opens with a section on theory—establishing the scientific language and ideas. Next, various techniques for measuring permittivity (dielectric constant and loss) and permeability are described for the range from dc to about 3×10^{10} cycles per second. Detailed information with charts and tables is included to guide the reader in the selection and application of methods for his specific problems. In addition, the most recent resonance methods are discussed: microwave spectroscopy and magnetic resonance.

The third section of the book offers the fullest account yet published on

dielectric materials and their application together with their properties and limitations. This discussion comprises: gases and vacuums, liquids, plastics and ceramics; their applications in power, distribution and electronics equipment, in capacitors and cables; and the operation of dielectrics as rectifiers, piezoelectric transducers and resonators, magnetic and dielectric amplifiers, and memory devices.

Section IV gives a short account of the requirements of the Armed Forces.

The final section presents in full the famous "Tables of Dielectric Materials" of the MIT Laboratory for Insulation Research. The tables cover complex permittivity and permeability measurements for more than 600 dielectrics in a frequency range of 10^2 to $2.5x10^{10}$ cps and for temperatures up to 500 deg C.

Dielectrics—Theory

DIELECTRICS AND WAVES *Arthur R. von Hippel, Professor Of Electrophysics, Massachusetts Institute of Technology, 8⅝ by 11¼ in., 284 pp. Published by John Wiley & Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. $16.00.*

This work is not limited to a narrow class of so-called insulators. It embraces any nonmetal—and even metals as a boundary case—where interaction with electric, magnetic, or electro-magnetic fields is under consideration. The book shows that dielectric analysis has gone far enough to permit the beginnings of dielectric systhesis, in which the properties of materials are tailored to order.

The work develops in two parts, the macroscopic and molecular approaches, to a general understanding of the phenomena. Polarization, magnetization, and conduction are the properties of matter at issue. Matter appears here as a storage medium and wave guide of electric and magnetic processes.

Part I introduces the complex permittivity and permeability as the basic parameters and derives the macroscopic theory in a unified manner for the electrical and optical frequency spectrum from the field and circuit aspect. Conversion formulas, nomographic charts, and tables of dimensions and units allow a convenient change-over to alternative parameters and systems.

Part II gives the molecular interpretation by considering the action of induced and permanent moments and of mobile charge carriers in gases, liquids and solids.

The Reader ABC His Mark

THE ABC SYMBOL, which appears at the head of this page, is your brand—the reader's brand—on this magazine. It stands for Audit Bureau of Circulations. It means that this magazine will stay in business only so long as it continues to serve its readers to their satisfaction.

That Bureau—known for short as ABC—is a voluntary, nonprofit, cooperative association founded in 1914 by a group of publishers, advertisers and advertising agencies who wanted to establish and maintain higher standards of publishing practices than then prevailed. Its primary and specific purpose was to set up yardsticks to appraise circulation values and to verify the claims of publishers as to their circulations. For the buyer of advertising space this provides an effective means to take some of the guesswork out of buying and to reconcile the conflicting claims of competing publishers. BUSINESS WEEK magazine has aptly described ABC as "the publisher's conscience—and cop."

BUT IN DOING that job, ABC performs another function of high importance to the readers of ABC member publications. It provides a constant pressure on the publishers to keep alive in their staffs a sense of primary responsibility to their readers. That is because the most simple and direct method of making a publication responsible to its readers is to place upon it a purchase price, whether by subscription or newsstand purchase. The right to purchase or to refrain from purchasing a publication gives to the reader and to no one else the power to pass effective judgment on the publisher's success in serving the reading public. Each paid publication will grow or languish, will prosper or fail, in proportion as it wins or loses the following of thousands or millions of readers. The readers, by their patronage, record their judgments as to whether the publisher and his publication are measuring up to their responsibility to them.

And that is where the ABC comes into the reader's picture. The newspaper or magazine that carries the ABC symbol on its masthead must in the first place be a paid circulation publication. Moreover, it must conform to the high standards set up by the Bureau as to terms of payment and accounting methods. And again it must open all of its books to the auditors of the Bureau on demand.

SINCE THE INFORMATION thus determined by thorough and impartial audit is periodically made public through the ABC statements and audit reports, it is constantly available to and universally used by advertisers who are considering the purchase of space in an ABC publication. These reports show the circulation trend, as verified and certified by ABC, and thus put the advertisers in a position to know whether or not the publisher is rendering satisfactory service to his readers.

Thus the publisher who submits his publication to the supervision and discipline of ABC affirms in the strongest possible manner that he recognizes his primary obligation is to his readers and that he owes his standing to a voluntary demand by those readers. It follows that the editors of ABC publications must be exceptionally alert to the desires of their readers and responsive to their needs, since any decline in circulation will soon show up in the ABC statements and audit reports.

THAT IS WHY we describe the ABC symbol as the reader's brand. It shows that a publication must be primarily responsive to him and that he holds in his own hands its success or failure. And that ABC symbol is not only a constant reminder to him of that fact, but also an equally constant reminder to all concerned that the reader's willingness to pay for the ABC publication is the acid test of its value to him and to the advertiser.

McGraw-Hill Publishing Company, Inc.

CONTROL TRANSMITTER

The Classified Advertising Section of **CONTROL** ENGINEERING

EMPLOYMENT: BUSINESS: **"OPPORTUNITIES"** :EQUIPMENT :USED OR RESALE

—RATES—

UNDISPLAYED

$1.50 per line, minimum 3 lines. To figure advance payment count 5 average words as a line.

Position Wanted undisplayed rate is one-half of above rate, payable in advance.

Box Numbers count as one additional line.

Discount of 10% if full payment is made in advance for 4 consecutive insertions.

DISPLAYED

Equipment Wanted or For Sale Advertisements acceptable only in Displayed Style.

Individual Spaces with border rules for prominent display of advertisements.

The advertising rate is $14.00 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request.

An advertising inch is measured 7/8" vertically on one column, 3 columns—10 inches—to a page.

New Ads Received by November 2nd at the New York office, 330 W. 42nd St., New York 36, N. Y., will appear in the December Issue subject to limitations of space available.

PROFESSIONAL SERVICES

- Control Systems
- Instrumentation
- Economic Studies
- Patents • Management
- Research • Design • Testing

GEORGE H. BATEMAN
Engineering Services
Custom design of electronic devices for remote and automatic control using magnetic amplifiers, transistors and vacuum tubes.
Box 345 Grand Rapids, Michigan

ROGER BARRETT BROSS
Consulting Engineer
SPECIAL ELECTRIC MOTORS
ELECTROMAGNETIC COMPONENTS
Design - Development - Manufacture
Testing - Application
25 Curtis Rd OL 3-9235
Box 157, Natick, Mass.

HANSON-GORRILL-BRIAN INC.
Specialized Control Systems
ELECTRICAL - ELECTRONIC
HYDRAULIC - MECHANICAL
One Continental Hill Glen Cove, N. Y.
Glen Cove 4-7300

INTERFERENCE MEASUREMENT LABORATORY
Consulting—Research—Development
Interference Study per Government Specifications
Shielded Space for Interference Investigation
Radio Interference Filters
907 East 51st Street Brooklyn 3, New York
Ingersoll 9-1765

ALBERT WIEBE and ASSOCIATES
Engineering Consultants
Improved Inspection Instrumentation for Quality Control — Automation. Elimination of Production Line Troubles. Product Re-Design for Greater Profits. Industrial Specialists in Government Contract Specification Performance Requirements.
550 Fifth Avenue, New York 36, N. Y.
Phone Plaza 7-3638 — Espl. 5-4971

Consult these SPECIALISTS
Let them save your time by bringing their broad experience in their specialty to bear on your problems.

YOUR CALLING CARD FOR A BRILLIANT FUTURE...

Bendix Missile Section is a major contractor in the U. S. Navy's guided missile program--a part of the "new look" in our defense plan. Our expanding program has many opportunities for senior engineering personnel: Electronics Engineers, Dynamicists, Servo-Analysts, Stress Analysts, Project Coordinators, and Designers. Take time now to look into the opportunities which Bendix can offer you. Write Employment Dept. M, 401 Bendix Drive, South Bend, Indiana.

REPLIES (Box No.): Address to office nearest you
NEW YORK: 330 W. 42nd St. (36)
CHICAGO: 520 N. Michigan Ave. (11)
SAN FRANCISCO: 68 Post St. (4)

POSITION WANTED

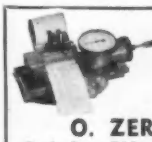
GENERALIST HAS 12 yrs. of sound experience in chem. process, military instruments, atomic energy for challenging application with smaller company. M. E., 34, $8000 plus, excellent references. Write PW-3969, Control Engineering.

Do you need competent men for your staff? Men experienced in system engineering? Men to fill executive, or technical positions? Advertise your need in this "Control Transmitter" Section

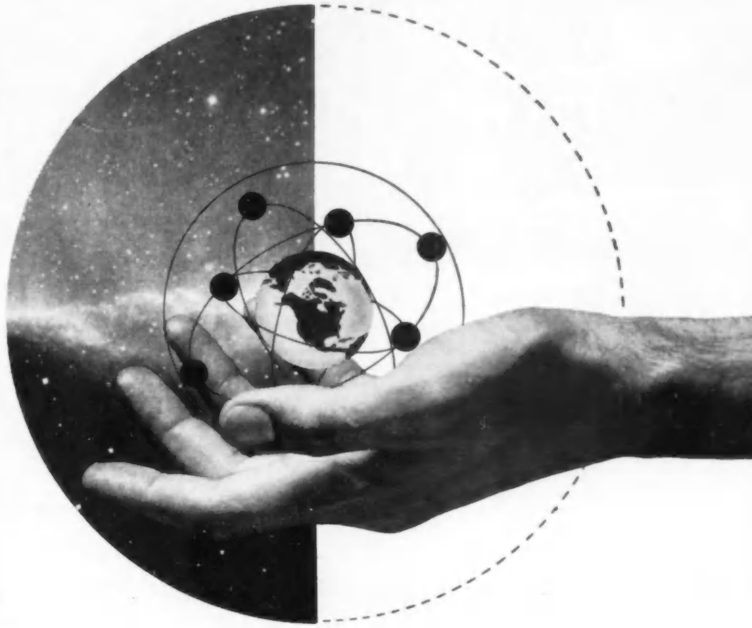
WHERE TO BUY

- EQUIPMENT
- MATERIALS
- SUPPLIES &
- SERVICES

For the Field of INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS



O-Z Hand TACHOGRAPH
Draws Graphic Speed Charts
RPM, FPM—FLUCTUATIONS
30-48000—Accuracy 0.5%
Write for Circulars
O. ZERNICKOW CO.
Park Row Bldg. New York 38, N. Y.



MAY WE HAVE YOUR ATTENTION?

The "CONTROL TRANSMITTER" serves as an active market place for buying and selling used and surplus elements and components of control systems. It will be consulted regularly by prospective buyers of such equipment offered by individual plants or dealers.

If you have used or surplus elements and components of control systems lying around idle in your plant, you can help other readers of the "CONTROL TRANSMITTER" who need such equipment by bringing it to their attention.

You may find bargains in hard-to-get components through the dealers advertising in this section. Make the reading of "CONTROL TRANSMITTER" a monthly habit.


TREMENDOUS SAVINGS IN
ELECTRONIC
WAR TERMINATION INVENTORIES
SAVE UP TO 85% • IMMEDIATE DELIVERY • EQUIPMENT FULLY GUARANTEED
SIMPLE DIFFERENTIAL
Size: 2-5/32" long x 1¼" dia.; bearing one end ½" O.D.; Shaft Size: 1" long, threads 8-32-¾" long, with bearing shaft ⅛" dia. x ¼" long. Gear on shaft end 1-7/16" dia., gear on bearing end 1¼" dia. Drive gear 25/32" dia.
Stock No. 101
$3.95 ea
FOUR GEAR SPIDER DIFFERENTIAL
2"—96 teeth—48 pitch gear; 4" of 48 pitch, 12 teeth pinon wire. Size: 8½" long x 4⅜" wide x 2" high.
Stock No. 102
$3.00 ea.
TRANSICOIL CORP. TYPE 2900
115 volt, single phase, 400 cycle. 115 volt, 2-phase, 400 cycle, 5500 R.P.M. Size: 1½" dia., 2" long. Shaft size: ⅛" dia., 9/16" long. ⅝" O.D. index ring.
Stock No. 103
$25.00 ea.
PIONEER TORQUE UNITS
Type 12602-1-A. Includes CK 5 Servo motor coupled to output shaft thru 125:1 gear reduction train. Output shaft coupled to autosyn follow-up (AY-43). Ratio of output shaft to follow-up autosyn is 30:1. Includes base mounting type cover for motor and gear train . . .
Stock No. 104
$34.95 ea.
SPIDER DIFFERENTIAL
Three spur gears. Size: 7½" long x 1¾" wide x 2¾" high.
Stock No 105
$5.00 ea.
SIMPLE DIFFERENTIAL
1:1 reverse ratio, 60 teeth on large gear; ¼" shaft. Size: 3" long with 1-15/16" dia.
$3.95 ea.
Stock No. 106
SAVE UP TO 85%
EQUIPMENT FULLY GUARANTEED
IMMEDIATE DELIVERY
C&H
SALES CO.
2176-E East Colorado St.
Pasadena 8, California
RYan 1-7393
WRITE OR WIRE FOR INFORMATION ON OUR COMPLETE LINE OF SURPLUS ELECTRONIC COMPONENTS. ALL PRICES NET F. O. B. PASADENA, CALIFORNIA.
SPIDER DIFFERENTIAL
Size: 6½" long x 1¾" wide with 3/16" shaft.
Stock No. 107
$2.50 ea.
GEAR DRIVE SPIDER DIFFERENTIAL
System includes seven gears and spider. Size: 5¼" long x 3½" wide x 3" high.
Stock No. 108
$5.00 ea.
INDUCTION MOTOR, KOLLSMAN
TYPE 1515B-0410
26 volt, 400 cycle, 2-phase. Size: 1-1/64" long; 15/16" dia. Shaft size: 1/8" dia.
Stock No. 109
$22.50 ea.
DUAL SIMPLE DIFFERENTIAL
1:1 reverse ratio on both. Size: 3¼" long x 1-7/16" dia. Shaft size: ⅛" and 5/32".
Stock No. 110
$7.50 ea.
SIMPLE DIFFERENTIAL
1:1 reverse ratio. Size: 6¾" long x 2¾" dia. Shaft size: 11/32".
Stock No. 111
$7.50 ea.
SIMPLE DIFFERENTIAL
Size: 5½" long x 2¼" dia. Shaft size: ⅜" on one end and 11/32" on other end. Hub is 1-3/32" dia. on each end.
$7.50 ea.
Stock No. 112
BENDIX ALTERNATOR
100 V.A.; 115 volt; 1 P.F.; 3 Phase; 400 Cycle; 2400 R.P.M.; Bendix Type 1631; Model 5; Style A Mounting: Flange 4¼" sq. 5/16" holes; 3¼" O.O. Ring for Centering; Unit is 7" long; Spline Shaft 12 T.; ⅝" dia.; 1-1/16" long; Wt. 10.5 lbs.
Stock No. 113
$49.50
PRECISION PLANETARY DIFFERENTIAL
1:1 reverse ratio, ring gear 3" dia., 120 teeth. Overall length 5¼". shaft dia. 11/32", ⅛" key on one end.
Stock No. 114
$7.50 ea.

Advertising In This Issue

DEPEND UPON

ITC®

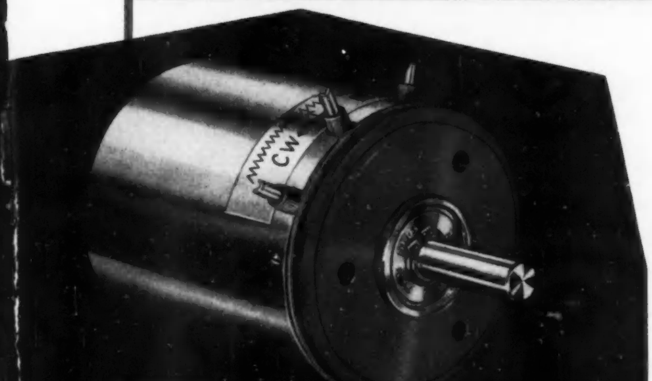
FOR THE

ULTIMATE

in

ACCURATE PRECISION MULTITURN POTENTIOMETERS

M10T



SM10T

TYPE SM10T Slide Wire Precision Multiturn Potentiometer with
INFINITE RESOLUTION
.05 % Linearity

Slide wire construction of resistance element firmly bonded to supporting drum.

Essentially zero end resistance.

- Integrated with system aspects of precision computers, servomechanisms and electro-mechanical instrumentation.
- Extremely precise mechanical tolerances, shaft diameter, concentricity and perpendicularity assure complete transfer of potentiometer accuracy to external systems.
- Universal mounting surface offers choice of servo-mount or precision pilot and tapped holes.

TYPE M10T Precision Multiturn Potentiometers featuring .025 % Linearity

Resistance elements are wound by a unique method which provides 100% production yields with extremely close linearity tolerances, and thus low production cost.

Winding may be corrected for specified resistive loads of at least ten times the potentiometer total resistance.

ELECTRICAL SPECIFICATIONS

Res. Range: 0-1000 ohms ± 5%
Ind. Linearity: ± .05% standard

Res. Range: 1,000 ohms to 10,000 ohms ± 5%
Ind. Linearity: ±.05% Std. ±.025% or better, special.

SPECIFICATIONS COMMON TO BOTH TYPES SM10T AND M10T

ELECTRICAL

Effective Electrical Angle: 3600° + 1°—0°
Ambient Temperature Range: −55°C to + 80°C

Equivalent Noise Res: 100 ohms maximum @ 4 rpm
Temperature Coeff. of Res. Wire: .00002°/C nominal

MECHANICAL

Base and Bearings: One-piece machined aluminum base houses spring-loaded ball bearings in a single through bore for rigid, low-friction shaft support.

Finish: Base is red alumilite, corrosion resistant per AN-QQ-A-696A. Cover stainless steel.

Mounting: Universal-type mounting offers choice of synchro or tapped hole mount with two high-precision pilots.

Shaft: Centerless ground stainless steel .2500" +.0000-.0003 diameter.

Mechanical Rotation: Angle between stops 3660° ± 2.5°

Stops: Rugged mechanical stops of lead screw type withstand torques exceeding 100 inch pounds.

Dimensions: Diameter 1.820", Length 2-1/16".

For full details write, wire or call

TECHNOLOGY INSTRUMENT CORP.

523 Main St., Acton, Mass.
COlonial 3-7711

PLANTS:

11029 Sherman Way, Sun Valley, California
Mail Address — Box 3941, North Hollywood, Calif. POplar 5-8620